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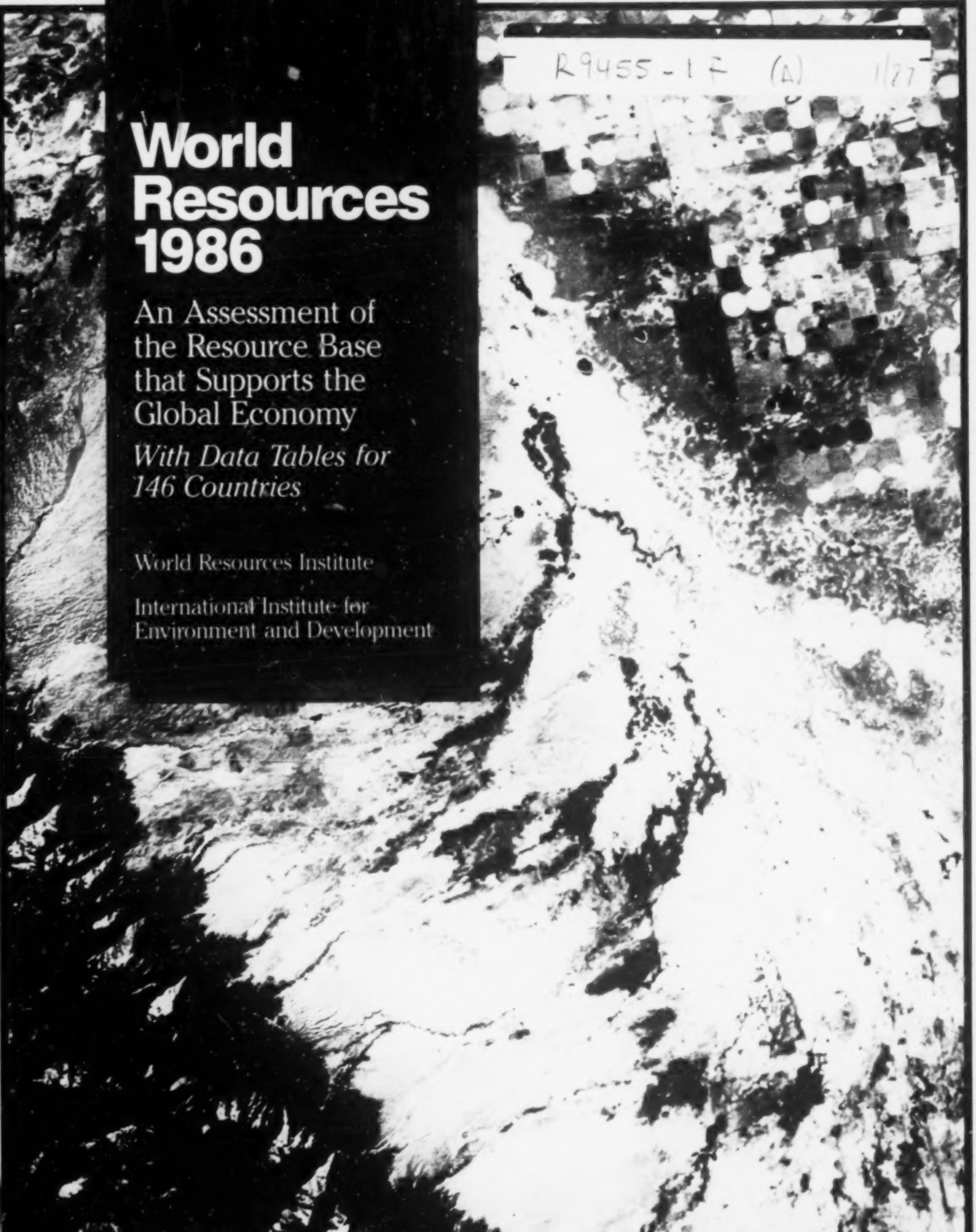

World Resources 1986

An Assessment of the Resource Base that Supports the Global Economy

With Data Tables for 146 Countries

World Resources Institute

International Institute for
Environment and Development

World Resources 1986

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World Resources 1986

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Preface

World Resources 1986 is intended to meet the critical need for accessible, accurate information on some of the most pressing issues of our time. Wise management of natural resources and the protection of environmental quality are intimately linked to vital objectives: alleviating poverty, achieving sustainable economic growth, promoting public health, coping with the pressures of rapid population expansion, and ensuring long-term political and economic stability.

With the surge of interest in resources and the environment has come a demand for reliable information and objective analyses of that information. At first, the information sought was mostly local: the impacts of pollution from an industrial facility, for example. Then, in the 1970s, attention shifted to the national level. Today, the focus is increasingly international: the loss of tropical forests and good farmland are problems on many continents; transboundary pollution, resource disputes between countries, and threats to the global commons all demand attention. International banks, multinational corporations, development assistance agencies, and relief and refugee organizations all confront issues rooted in resource use, environmental quality, and population pressures.

The famine in Africa and countless other situations large and small throughout the world confirm the need for a regular, global report addressing these issues. Our hope is that *World Resources 1986* and subsequent volumes will meet this need by:

- Supplying basic information and reliable, current data on international conditions and trends to a broad audience, and, by doing so, providing a common basis for discourse; and
- Presenting objective analyses that are essential for identifying priority issues, resolving disputes, and formulating wise policies in the public and private spheres.

The task we undertook was ambitious and complex. By pooling the expertise of our two institutions and drawing on experts from around the world, we are confident that we are on the right road. If this report leads to improved understanding and action, and to a demand for more reliable and complete data in the future, we shall be well satisfied. And we are confident that, as with many undertakings of this type, subsequent volumes will improve on the shortcomings of the first.

There are many people to whom we are indebted and without whom *World Resources 1986* could not have been published. The *World Resources* staff, led in the final critical months by WRI Vice President, Dr. Jessica T. Mathews, deserves first mention; a more dedicated group would be hard to find. The Editorial Advisory Board, chaired by Dr. M.S. Swaminathan, was a steady source of encouragement and advice. One member of this board, Robert S. McNamara, deserves special mention for his original suggestion to produce a report of this type. Numerous collaborators and reviewers, both within and outside our two organizations, made valuable contributions. They are listed in the Acknowledgments.

We wish to note our deep appreciation of those organizations that support this effort financially: The Ford Foundation; the United States Agency for International Development; The J.N. Pew Jr. Charitable Trust; the John D. and Catherine T. MacArthur Foundation; the United Nations Environment Programme; The German Marshall Fund of the United States; The William and Flora Hewlett Foundation; The World Bank; the United Nations Development Programme; and the United States National Aeronautics and Space Administration.

A final note. Readers of *World Resources 1986* will see immediately that it addresses some of the most heartrending and disturbing issues of our time. There have been solid successes and great failures in dealing with these issues. The experience of the last two decades provides ample grounds for both optimistic and pessimistic assumptions about the future. Clearly, the challenges described in this volume will be met only if concerted efforts are made, with some urgency, to change many current policies, to strengthen and multiply successful initiatives that have been taken, and to carefully exploit emerging technologies. Realizing a brighter future will require both energetic initiatives by governments and larger roles for those outside government, including private business, the scientific community, and nongovernmental organizations of all types. Our hope is that *World Resources* will facilitate such a response.

Brian W. Walker
President
International Institute for Environment and Development

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President
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We are indebted to a host of people who contributed to making *World Resources 1986* a reality. First and foremost are those who, early in the project, shared our view that this would be a worthwhile undertaking and provided the financial support to make it possible. We thank: The Ford Foundation; the United States Agency for International Development; The J. N. Pew Jr. Charitable Trust; the John D. and Catherine T. MacArthur Foundation; the United Nations Environment Programme; The German Marshall Fund of the United States; The William and Flora Hewlett Foundation; The World Bank; the United Nations Development Programme; and the United States National Aeronautics and Space Administration.

Our colleagues at the International Institute for Environment and Development and at the World Resources Institute ungrudgingly interrupted their own work time and again to answer our pleas for advice and criticism. They drafted, reviewed, corrected, found leads to new material, and in general provided invaluable assistance. Without their help it could not have been done. We are deeply grateful to them all.

Several writers and technical experts assisted in the actual drafting of chapters. They are: Libby Bassett (Policies and Institutions), John Beddington (Oceans and Coasts), Mark Bello (Human Settlements), Chris Bernabo (Atmosphere and Climate), Nora Berwick (Oceans and Coasts), Malin Falkenmark (Freshwater), John Gulland (Oceans and Coasts), Jorge Hardoy (Human Settlements), Peter Harnik (Food and Agriculture), Frank Hebard (Oceans and Coasts), William Lanouette (Policies and Institutions), Norman Myers (Wildlife), Margie Pa[illegible]ck (Oceans and Coasts), Jeannie Peterson (Population), Richard Sandbrook (Policies and Institutions), David Satterthwaite (Human Settlements), Napier Shelton (Wildlife), Dean Treadwell (Forests and Rangelands), and Robert Winterbottom (Forests and Rangelands). Responsibility for the chapters as they now appear rests with the *World Resources* staff, but each of these individuals shares substantial credit for what is new, valuable, and insightful in this book.

Dozens of individuals in universities, governments, international organizations, research institutions, and elsewhere generously provided data (some of it not previously published), reviewed drafts, or wrote short sections. The length of the list does not diminish their individual contributions or our gratitude to each of them. They are: Christian Averous, Silvio Barabas, Geoff Barnard, Peter Bartelmus, Ann Bartuska, Burton Bennett, David Bennett, Nancy Birdsall, Helen Bothwell, Marcia Brewster, Harrison Brown, Lester Brown, Robert Bruck, Sharon Camp, Frank Carter, Ramesh Chander, Garry Charnock, Wan-li Cheng, Thomas Conway, Ken Cook, Cliff Curtis, Ellis Cowling, Julio Davila, J.L.T. Davies, Annick de Marffy, Louis DeMouy, Robert Dickinson, David Flood, Robert Fox, Fritz Fuhr, Silvio Funtowicz, William Geddes, Katherine Gillman, John Gladwell, Roger Goss, William Gregg, Elizabeth Gormley, Gunnar Hagman, Andrew Hamer, Jeremy Harrison, Carl Haub, Howard Hogg, Martin Holdgate, Bruce Horwith, Robert Johnston, Andreas Kahnert, John Kammerer, Charles Keeling, Lee Kimball, Glenn King, Reiner Kramer, Christine Kronauer, Hans Landsberg, Wo Yen Lee, Maureen Lewis, James Listorti, Eduardo Loayza, James MacKenzie, Gordon Mackerron, James MacNeill, Arthur McKenzie, Jean Margat, Joan Martin-Brown, Elaine Matthews, Tom Merrick, Hugh Miall, John Miller, Lawrence Minear, Liz Mills, Peter Odell, Phil O'Keefe, Wallace Parham, David Pearce, J.B. Penn, Arthur Purcell, Leroy Quantz, Bernhard Rami, J.R. Ravetz, John Reuss, Jane Robertson, Ralph Rotty, Francesco Sella, Peter Schutt, John Scott, Alfredo Sfeir-Younis, Jose Shapouri, Alec Dawson Shepherd, Mary Stafford Smith, Richard Smith, Rezso Solymos, Odyer Sperandio, Patricia Strauch, Thomas Stoel, John Surrey, Jane Thornback, Vladimir Uspensky, Carl von Hake, Howard Walton, Phillip Wardle, Greg Watters, Susan Wells, Edward Wolf, and William Zajac.

Producing this volume was a gargantuan task. Mary Paden, our Production Manager, led a talented and dedicated team of copy editors, fact checkers and proofreaders who worked long and unpredictable hours: Katherine Hoskins (who also produced the Index), Esther Runnalls, Sheila Mulvihill, Richard Danca, Leslie Lin, Diana Field, and Anne Norman. Novella Murray, Project Secretary, supervised a superlative team, including Evelyn Bland, Carlton Marbley, Harristeen Soard, and Linda Swerdloff, who endured a grueling work schedule. Maurice Allen and intern Susan Warford were indispensable in helping to prepare Part IV. We thank them all for their commitment, skill, and high professional standards.

Finally, we would like to acknowledge the excellent design and production work of The Forte Group of Alexandria, Virginia.

J.T.M.
D.H.

Note to the Reader

This is the inaugural volume of an annual series. It does not, therefore, try to cover all the important topics in the vast field of resources and the environment. Readers surprised by the absence of a particular subject should be reassured: it will appear in a subsequent volume.

For example, this year's Chapter 2, on "Population," focuses on the basic determinants of growth: fertility and mortality. Next year's chapter will deal with aspects of health and nutrition. In this edition, Chapter 3, "Human Settlements," discusses urban life. Subsequent editions will cover rural settlements, land tenure, and other issues not treated here. Chapter 6, "Wildlife and Habitat," explores topics related to endangered species and ecosystems and various means of protecting them. Very different issues will appear subsequently—from the management and economic use of wild species to advances in biotechnology and their implications for wildlife. This year, Chapter 9, "Oceans and Coasts," covers fisheries and three important coastal ecosystems. Next year's chapter will treat marine pollution. And so on.

Beginning next year there will be an additional chapter on biogeochemical cycles. It will cover the emerging understanding of the global cycles of carbon, nitrogen, sulfur, phosphorus, and methane, how they affect life on Earth, and people's role in altering them.

A characteristic feature of environment and resource issues, as it is of most living systems, is that everything is connected to everything else. Consequently, there is no wholly satisfactory way to organize a volume such as this: any plan creates artificial divisions. For example, Chapter 8, "Freshwater," treats water as a resource. But water's principal use, irrigation, is also covered in Chapter 4, "Food and Agriculture," because irrigation is a prime determinant of crop productivity. Many cross-references are noted in the text, but including them all would be disruptive. The reader is urged to consult the Contents and the Index as well.

Another characteristic of these issues, and a principal motive for undertaking this project, is the gaping holes in basic knowledge. In Chapter 5, "Forests and Rangelands," for example, the reader will discover that reliable data on the conditions of the world's rangelands simply do not exist. The very high failure rate of rangeland management projects is not unrelated, one suspects. Similarly, Chapter 9 in Part IV, "Freshwater," reveals how poor the data are even for such a basic resource as water. The best data on water availability are more than ten years old and are not reliable. Information on water quality and use is often worse: values for many basic indicators have not been measured, and those that have been measured are often not comparable among countries. At the present level of effort, it may take as long as a decade to establish reliable water quality trends for much of the world. We hope that *World Resources* will alert policymakers throughout the world to the limitations of existing data and to the pressing need for improvement.

There is no single theory or approach that can be used to identify the most important indicators of world resource use and environmental quality. Lacking one, we have tried in the Part IV tables to cover all major resources and to select a few data series that bear upon important policy issues for each. Their selection was heavily influenced by the availability of comparable data for most countries and of time series data. When the latter are not available, we include data on significant similarities and differences among countries and regions or make comparisons with established guidelines or standards.

Part IV is divided into 12 subject areas corresponding to the 10 in Part II, plus added chapters on "Economic Development" and "Land Use and Cover." Each chapter (except "Atmosphere and Climate") opens with a table that contains data for 146 independent countries and, where applicable, totals for continental groupings (including the Soviet Union) and for the world. (Countries with estimated 1985 populations of less than 240,000 people are omitted. Data for these countries are included in the continental and world totals.) Tables for each resource include the extent of the resource, the quality or condition of the resource, and its use or value. Statistics on per capita use or availability and other measures of distribution are often included.

By and large, this report covers the recent past and the present; it does not attempt to project the future. However, trends are presented and discussed, especially where projections have been the subject of intense study, as in the case of population and of energy.

We were aware from the start that this was an ambitious undertaking. Only a sense of its potential value—and the expectation of a partnership with a growing circle of users—led us to push ahead with the project. For *World Resources* to serve the needs of you, its readers, we must know what they are. What should be changed, strengthened, added, dropped? We welcome your suggestions and comments.

Perspectives **Part I**

1. An Emerging Agenda

Among the hundreds of topics addressed in this volume, a number stand out, either because they demand urgent remedial action, because they are new problems that could heavily affect future environment or policy, or because of their pervasive impact on the human condition. We have chosen several to review here, highlighting key points from Parts II, III, and IV. They illustrate how the subjects treated in separate chapters are in fact bound in an indivisible web of cause and effect and, we hope, suggest the depth and scope of the material to be found in the rest of the volume.

Because the purpose of *World Resources* is to contribute to better management of the environment, the emphasis here is on problems—situations that call for attention and action, whether it be research, data collection, applying proven management strategies, or adopting new policies. This does not mean that conditions everywhere are worsening, or that the future will necessarily be gloomy. The problems are eliciting some positive responses, many of them described in the Recent Developments sections of this book and in Chapter 11, "Policies and Institutions", that could substantially alter present trends. Mankind today has unprecedented wherewithal to determine its future circumstances—for better and worse. Notwithstanding the formidable challenges posed by population growth, widespread resource degradation, and diverse sources of pollution, there are few, if any, problems on the horizon that are in any fundamental sense unsolvable.

THE ENVIRONMENT AND HUMAN HEALTH

Environmental quality and successful resource management affect human health far more than is widely recognized in a world where "health care" is so often equated with "medicine," and high technology medicine, at that. Yet the demographic transition from high to low mortality rates in the developed countries generally predated the availability of specific therapies. It came with the advent of basic environmental amenities: clean water and sanitation, and improved nutrition and living conditions. (See Chapter 2, "Population": The Demographic Transition, Figure 2.7, and Box 2.1.)

Medicine, principally vaccines and antibiotics, has been a significant factor in the much sharper declines in mortality rates in today's developing countries, but the dominant role is still played by improved living—that is to say, environmental—conditions. The biggest drop in mortality has come in the shaky first year of life. Despite the rapid improvements of the past three decades, however, infant mortality is still one of the clearest measures of the gap between developed and developing countries; it ranges from fewer than 1 percent of live births in many western European countries to more than 15 percent in some Asian and African nations. (See Chapter 2, "Population": Infant Mortality Rates, and Box 2.2; and Part IV, Table 2.4.)

The availability of sufficient food is the first requirement for a healthy life. Despite steady worldwide gains in agricultural production through the decade, the grim fact remains that there were more hungry and malnourished people in 1980 (*before* the African drought) than there had been ten years earlier. In 1980, excluding China, 700—800 million people ate fewer than 90 percent of the calories international standards deem necessary for an "active working life." Of these, about half ate fewer than 80 percent of the standard, an insufficient number of calories to prevent "stunted growth and serious health risks." Poverty and misguided government policies, not inherent resource limitations, are the reasons for this growing hunger in a world of agricultural surpluses. The ties run in both directions. Past resource degradation deepens today's poverty, while today's poverty makes it terribly hard to care for or restore the agricultural resource base; to find alternatives to, or carefully manage, deforestation; to prevent desertification; to control erosion of irreplaceable topsoil; and to replenish soil nutrients. (See Chapter 4, "Food and Agriculture": The Resource Base, and Table 4.1.)

A sufficient calorie supply is not all that is necessary for adequate nutrition: clean drinking water is also essential. Chronic intestinal infections from contaminated water cause malnutrition in thousands upon thousands of towns and villages where there is enough food. Throughout the developing world, water polluted by sewage or industrial wastes causes disease and death. In India for example, 70 percent of all surface waters are polluted. As the Yamuna River flows through Delhi, it picks up a staggering *daily* load of 200 million liters of untreated sewage and 20 million liters of industrial wastes (including 500,000 liters of DDT wastes). Overall, four out of five people in the developing countries had no sanitary facility—not even a pit or bucket latrine—in 1980. The same proportion—80 percent—of childhood deaths is due to water-borne disease. Ironically, many of the disease vectors flourish in the standing water of irrigation systems created to aid food production. Water shortages are also a major cause of suffering and death. Sometimes they are the result of a drought or other natural disaster, but often there are human causes: the disruption of hydrological cycles by deforestation and loss of soil cover, over-use of groundwater, or excessive erosion. Together, water shortage and contamination cause 25,000 human deaths daily. (See Chapter 8, "Freshwater": Public Water: Drinking Water and Sanitation, Water Pollution, and International Drinking Water and Sanitation Decade.)

Environmental impacts on human health are widely felt in the developed world as well. There, pollution, more often than resource degradation, is the culprit. Air pollution standards, based on demonstrated harm to human health, are exceeded all over the world. While the trends for regulated pollutants such as sulfur dioxide, suspended particulate matter, nitrogen oxides, and carbon monoxide are generally improving in the developed countries, a host of potentially serious health problems remains. Among these are the effects of nitrogen oxides, which may be more serious than yet recognized; the still uncontrolled status of fine particulate matter; and unregulated trace emissions of organic compounds, toxic metals, and fibers, which may be causing cancer, birth defects, and other disease. (See Chapter 10, "Atmosphere and Climate": Emissions and Ambient Air Quality, and Problems Remain.)

While the quality of surface waters in the Organization for Economic Co-operation and Development (OECD) nations is generally improving, the pollution of groundwater by human wastes and toxic chemicals is a growing concern. In the United States alone, 1,000–2,000 hazardous waste dump sites are considered potential threats to groundwater reserves. Once groundwater is contaminated, it can take decades, centuries, or even longer before natural processes eliminate the pollution. (See Chapter 8, "Freshwater": Groundwater.)

Other environmental threats to human health have been largely ignored in developed and developing countries alike. Pesticides are a striking example. Despite more than three decades of rapid growth in pesticide use, astonishingly little is known about their effects on the health of those who labor in the fields. Reliable data on rates of poisonings and death do not exist, though more than enough is known to warrant serious concern. Even when a pesticide has been identified as dangerous and banned in some countries, its use may continue and even spread in others. In fact, in 1979 nearly one-third of the pesticides exported by the United States were not registered for use at home, and of these, 20 percent had been canceled or suspended by the government as unsafe to human health or the environment. (See Chapter 4, "Food and Agriculture": Pesticides.)

This is no more than a sampling of the myriad ties between environmental quality and human health. Despite dramatic progress in some regions, pollution of air, water, and soils still poses significant known and potential health threats. But the lack of adequate nutrition, of potable water, and of sanitation remain the principal causes of human ill health in the world today, all of them in the purview of environmental and resource policy, not of medicine.

TROPICAL DEFORESTATION

The picture that tropical forests present of dense, almost uncontrollable growth is deceptive. In part because of their tremendous genetic richness, these forests are actually an extremely fragile ecosystem, highly susceptible to damage from human activities. Once damaged, the entire ecosystem can quickly unravel in a now all-too-familiar sequence: interruption of nutrient cycling; loss of soil fertility; extinction of plant and animal species; soil erosion; downstream siltation, flooding, and damage to irrigation systems; and (especially in the dry tropical forests) acute fuelwood shortages. The effects ripple through agriculture, energy supply, water quality, and nearly every aspect of the daily life of 1 billion people. The end result is biological impoverishment and human suffering writ large.

Exactly how fast the tropical forests are disappearing has been hotly debated, party because of the use of differing definitions of deforestation. Some statistics reflect only complete forest loss, while others measure the partial damage caused by such activities as selective logging, road building, grazing, and fuelwood gathering. The bottom line is that somewhere between 25–40 percent of the original extent of the tropical forests was lost by 1980. The best current estimate is that about 80,000 square kilometers—an area the size of Austria—is lost, that is, converted to non-forest uses, each year. About one-and-a-half times as much is damaged to some degree. By the year 2000, if current trends continue, about 12 percent of the moist tropical forests that remained in 1980 will be gone, as will slightly less—about 10 percent—of the remaining dry tropical forests. Rates of loss vary enormously among countries, and none of the data are as good as they should be, but the overall trend and its gravity for mankind are beyond question. (See Chapter 6, "Wildlife and Habitat": How Many Species?, Extent and Condition of Ecosystems; and Chapter 5, "Forests and Rangelands": Focus on: Deforestation in Developing Countries.)

Most immediately, the continuing loss of these forests spells the disappearance of much of the planet's biological diversity. Though today's tropical moist forests cover only about 7 percent of the earth's land area, they are believed to be home to half of its species. No other ecosystem rivals them in genetic luxuriance. Whereas a hectare of temperate forest might contain as many as 10–15 tree species, the same area of Amazonian rainforest might hold more than 200. Only 1.7 million of the planet's estimated 5–10 million species (the total may be double or triple that number) have yet been identified, so millions more remain to be found in the tropical forests. At current rates of tropical forest loss, then, a million species—10–20 percent of the earth's total—could become extinct by about the year 2000. Most will disappear without ever having been discovered. (See Chapter 6, "Wildlife and Habitat": Distribution and Diversity, How Many Species?, Extinction, and Table 6.2.)

What this means is that the planet will lose a sizable portion of its genetic heritage, and mankind a resource of immense—if immeasurable—value. The genetic ancestors of nearly all of today's agricultural crops are found in the tropics. Plant breeders must turn to these relatives for the genes necessary for pest- and disease-resistance, for other crop improvements, and for adapting present-day crops to changing conditions. Medicine relies on the forests as well: more than half of modern medicines come from plants, a great many of them tropical plants. Industrial products from the tropical forests include everything from rubber, rattan, turpentine, and bamboo to a galaxy of fibers, resins, steroids, and dyes. The psychological, cultural, and aesthetic value of the wildlife itself can be sensed, though not measured. (See Chapter 4, "Food and Agriculture": The Seed Wars; and Chapter 6, "Wildlife and Habitat": Species.)

The pressure of growing populations on the dry tropical forests is creating a new energy crisis, even as the oil crisis recedes. Half the world's people depend on biomass energy—principally fuelwood—for their daily needs. About 60 percent of them, 1.5 billion people, are cutting wood faster than it can grow back, creating a fuelwood deficit that is expected to double by 2000.

The rural poor are the principal victims. As population densities rise, people are forced to shift from collecting and using dead wood to using grass, twigs, whole branches, and ultimately to chopping down entire trees. As supplies dwindle, the amount of time spent collecting a family's fuelwood rises to as high as 300 workdays per year. Economizing on the amount of wood used eases the shortage: people light smaller fires and quench and reuse the embers rather than letting them burn out. Surveys in Mali and Niger show annual fuelwood consumption as low as 500 kilograms per person per year, less than a quarter of that used in areas where fuelwood is more abundant. But there is a limit: the household fire supplies not only the energy to cook food and heat water, but also serves as a source of lighting and space heating, as an insect repellent and defense against wild animals, and as the focal point for family life. Nearly 100 million people in Africa cannot meet their minimum fuelwood requirements even by overcutting trees. (See Chapter 7, "Energy": Biomass Fuels, and Focus on: Fuelwood Scarcity; and Chapter 5, "Forests and Rangelands": Fuelwood Production.)

When wood supplies run out, people are forced to turn to the next available source, usually animal dung or crop residues. Here the effects of deforestation begin to touch agriculture, for dung is a valuable fertilizer, and the recycling of crop residues is essential for soil maintenance and protection against erosion. An estimated 400 million tons of dung are burned annually where fuelwood is scarce. The sacrifice of this fertilizer is estimated to depress grain harvests by over 14 million tons, an amount greater than annual food aid to all the developing countries. In China, which suffers from acute energy shortages in its rural areas, as much as 75 percent of available crop residues are used for fuel, whereas in the United States 70 percent are recycled. (See Chapter 4, "Food and Agriculture": Expanding the Cropland Base, and Focus on: Erosion.)

There are other impacts as well. Deforestation on steep upland watersheds leaves the unprotected soil to wash rapidly away, increasing siltation and causing flooding downstream. The useful life of expensive hydroelectric projects can be sharply curtailed as their reservoirs silt up. The Anchicaya Dam in Colombia, a not atypical example, lost 25 percent of its storage capacity in just two years because of deforestation in its watershed. Irrigation systems, another costly investment, can also be badly disrupted. (See Chapter 4, "Food and Agriculture": Focus on: Erosion.)

Taken as a whole, the rate of deforestation in the tropics exceeds the rate of reforestation by ten to twentyfold. Yet there are grounds for optimism about the future. Within the past few years, the fate of the tropical forests, once the concern of a relatively small community of conservationists and foresters, has become a focal point of activity for a rapidly expanding number of nongovernmental organizations and governmental agencies. Afforestation projects have become integral elements not just of forestry programs, but of broader programs designed to address desertification, water quality, erosion, energy shortages, and rural hunger. Citizen "grass roots" efforts have proliferated in everything from village tree plantings, to establishing seedling nurseries, promoting agroforestry, and pushing for the reform of government policies that intentionally or inadvertently encourage deforestation. There is not much time for these efforts to succeed. A far larger gathering of public support, national commitment and international assistance is urgently needed. (See Chapter 5, "Forests and Rangelands" Reforestation and Forest Renewal, Investment in Forestry: Priorities and Needs; and Chapter 11, "Policies and Institutions": Citizen Efforts and Public Support.)

THE ATMOSPHERE AS A SHARED RESOURCE

Not long ago air pollution seemed a relatively well-defined environmental issue. A few air pollutants—sulfur dioxide, particulate matter, nitrogen oxides, and carbon monoxide—went up and then came down nearby, causing visibly dirty air, noticeable effects on human health, and sometimes a circle of dead or dying plants around the emissions source. Today the situation is very different. The number of pollutants demanding attention has multiplied. Emission sources and affected areas may be separated by hundreds, even thousands of miles, so that regulation is no longer a local or even a national matter, but often an international one. The atmosphere itself is no longer seen as simply the passive receptacle of pollution. Now it is understood to be an active participant in an extraordinarily complex set of chemical and meteorological interactions in which emissions are mixed, transformed, and transported. The continuity of the atmosphere has been further dramatized by the emergence of two *global* pollution problems—the greenhouse warming, and the depletion of stratospheric ozone—emphasizing the degree to which the atmosphere is a resource shared by, and perhaps someday to be jointly managed by, the entire planet.

Concern over acid deposition has been the prime mover behind the shift in attention from the local to the regional and international scale. As emissions of sulfur dioxide and nitrogen oxides travel long distances in the atmosphere, they are chemically transformed into sulfuric and nitric acids. These return to earth in rain, snow, fog, and mist, and as dry deposition. Emissions can remain in the atmosphere anywhere from hours to weeks, depending on meteorological conditions, and can therefore be transported quite far or hardly at all. In eastern North America and Europe, about one-third of deposited sulfur comes from relatively close by (less than 200 kilometers away), one-third from medium distances (200–500 kilometers), and one-third from long distances (more than 500 kilometers). Central Europe measures about 2,000 kilometers from the beaches of Normandy to the eastern edge of Czechoslovakia. In that space (and about half as far from north to south) there are about a dozen nations. Obviously, tracing responsibility for what comes down, as a prerequisite to regulating what goes up, is a difficult task; achieving effective control without international cooperation is impossible. (See Chapter 10, "Atmosphere and Climate": Transport of Atmospheric Pollutants.)

The exact degree of acidification an individual body of water will undergo depends on many local factors, including composition of bedrock, type of surrounding vegetation, time of year, forest-soil interactions and more. But these and other measures allow scientists to identify acid-sensitive regions. For example, Sweden estimates that about 40,000 of its 90,000 lakes are acid-sensitive. Of these, 4,000 are already highly acidified, 18,000 are partly acidified, and 20,000 are at risk if present trends continue. The country also has 90,000 kilometers of acidified streams. Damage to fish ranges from temporary disruption to the loss of whole populations. Similar situations exist in Norway, the United States, Canada and other countries. (See Chapter 10, "Atmosphere and Climate": Deposition, and Acidification of Aquatic Ecosystems.)

Acid deposition is also implicated in the far more complex phenomena that are damaging terrestrial systems, including soils, crops, man-made structures, and, especially, forests. In a broad swath of destruction, more than 7 million hectares of forests in 15 European countries have been stricken by a disease syndrome dubbed *Waldsterben* (forest death) that is thought to be caused by the actions of many pollutants acting in combination with biological and physical stresses (insects, fungi, weather, etc.) (See Chapter 12, "Multiple Pollutants and Forest Death": Box 12.1.)

Unlike previous forest declines, *Waldsterben* in Europe is neither localized nor limited to one or a few tree species. It affects nearly every important species in Central Europe, including types of spruce, fir, pine, beech, birch, maple and oak. (In the United States a related but distinct phenomenon is at work, so far affecting only conifers. See Table 12.2.) Once the signs of damage are visible, the syndrome can progress with devastating speed. Eight percent of West German forests were reported dead or damaged in 1982. One year later the figure was 34 percent. By 1984, the toll stood at 50 percent. (See Chapter 12: Introduction, Historic Forest Decline, and Table 12.3.)

The causes and mechanisms of *Waldsterben* are still so mysterious that the possible triggering agents include a long list of airborne suspects: ozone and other oxidants including PAN (peroxyacetyl nitrate) and PPN (peroxyproprionyl nitrate); total biologically-available nitrogen compounds; other plant-damaging gases such as nitrogen oxides, sulfur dioxides, and fluorine; toxic metals including lead, cadmium, zinc, and copper; acid deposition; and growth-altering organic chemicals. The symptoms of damage are so varied that ten different mechanisms involving these substances have been proposed. Other hypotheses suggest viral and other non-pollution-related causes. But increasingly the finger is being pointed at air pollution. Of the 19 regional forest declines in Europe and North America over the last 50 years, air pollutants are believed to have been the primary or contributory cause in at least seven. With one exception, all of these declines developed (or were first noticed) during the last eight years. (See Chapter 12: The Chemical Etiology of *Waldsterben*, and Historic Forest Decline.)

Despite the bewildering array of symptoms, scientists have managed to identify some characteristic features of the disease, including some that have never been described before. The pace of research in the past few years has been urgent, but as of this writing little is known with certainty. *Waldsterben* does seem to be a distinct phenomenon, unlike previous forest diebacks caused by pollutants, pathogens, or climatic stress, and it appears to be the result of multiple air pollutants acting additively or synergistically in ways yet to be deciphered. (See Chapter 12: Forest Damage, and The Burden of Research.)

Like *Waldsterben*, human impact on the stratospheric ozone layer has proven to be a particularly difficult phenomenon to understand. The principal causative agent is known: a group of very stable, and therefore long-lived, chemical compounds known as chlorofluorocarbons (CFCs) used primarily in aerosols, and refrigeration. The principal result—greater ultraviolet radiation from the sun reaching the earth—is also clear. The likely effects are less well known. An increase in non-melanoma skin cancer is generally agreed upon, while damage to plants and animals, suppression of human immune systems, an increase in skin melanomas and other possible effects are controversial. However, estimates of the *rate* at which the protective ozone layer is being depleted, and therefore of the urgency of the issue, have fluctuated for years as scientists have learned more about the many processes that determine atmospheric chemistry and climate. Depletion is no longer even the sole subject of study: the various effects on global climate of ozone's vertical redistribution now further complicate the picture. Recently, concern over the future of the ozone layer has grown (as, unfortunately, have emissions of CFCs) to the point that nations have undertaken an unprecedented negotiation to protect this global resource. (See Chapter 10, "Atmosphere and Climate": Potential Changes in Stratospheric Ozone, and Vienna Convention For the Protection of the Ozone Layer.)

Dwarfing even ozone depletion in its scope and complexity is the apparent greenhouse warming of the planet. Carbon dioxide emissions, principally from the combustion of fossil fuels, account for about half of the greenhouse effect. The other half is due to the combined role of many other gases, principally nitrous oxide, methane, CFCs, and tropospheric (lower atmosphere) ozone. These gases are transparent to most of the incoming radiation from the sun, but absorb the heat radiated back by the earth, thereby heating the atmosphere—hence the "greenhouse" effect. If present trends continue, the global average surface temperature is predicted to rise 1.5–4.5°C in less than 50 years. While no one *feels* an average global temperature, the effects on climate are expected to be most definitely noticeable, with possibly severe consequences for people and wildlife. A sea-level rise of uncertain magnitude is predicted, as are regional changes in rainfall, growing season, normal peak temperatures, and numerous other climatic characteristics. (See Chapter 10, "Atmosphere and Climate": Focus On: The Greenhouse Effect.)

The greenhouse warming, like stratospheric ozone depletion, has been termed a "planetary experiment," one so complex that nearly every prediction is uncertain. Unlike a scientist's tinkering, however, the outcome is one mankind will have to live with. Therefore, despite the daunting technical uncertainties, scientists are uncharacteristically calling on governments to consider greenhouse impacts as they plan future investments, and to begin an active collaboration between scientists and policymakers to explore alternative policies, especially in energy conservation, in order to slow, prevent, or adapt to a greenhouse-induced climate change. Success in these efforts will demand ideas as new—and a degree of international cooperation as unprecedented—as the phenomenon itself. (See Chapter 7, "Energy": Energy Projections; and Chapter 10, "Atmosphere and Climate": Box 10.1.)

SOIL DEGRADATION

With more and more people on the planet, there is a constant search for new cropland. It is not easy to find. Areas with the greatest need tend to have the least available land. Land not being used generally has problems of soil type, climate, accessibility, or topography that severely limit its potential. Or it may have other uses, such as wildlife habitat, that must be sacrificed if the land is to be converted. Ten years ago, two-thirds of the population of the developing world already lived in countries rated "land scarce" or "extremely land scarce" (countries in which more than 70 percent of the potentially arable land is being cultivated.) By 2000, there is projected to be about half a hectare of cropland per person in the industrial market economies, about one quarter of a hectare in the centrally planned economies, and an average of 0.19 hectares per capita in the developing countries—only half that amount in East Asia. (See Chapter 4, "Food and Agriculture": Expanding the Cropland Base, and Table 4.2.)

Ironically, while the search goes on for new agricultural land, the existing crop and rangeland base in the arid and semi-arid regions is being steadily diminished because of changes that reduce or completely destroy its agricultural productivity. Collectively these changes are somewhat misleadingly called "desertification." The appearance and spread of sand sheets and dunes may be, but often is not, involved. Depending on the local environment and what it is being used for, impoverishment and loss of vegetation, soil compaction and loss of nutrients, soil erosion and salinization, and loss of surface water and ground water, may all be part of the process.

Desertification usually begins with a drying of the soil that results from excessive stress, for example from overgrazing rangeland. The native vegetation then declines, producing less organic matter to maintain soil fertility. The soil can become so hard that the heavy but infrequent rains characteristic of arid regions have no chance to percolate into the soil, where they could recharge underground aquifers and provide moisture to plants. Instead the water runs off, leaving behind the aptly-named "erosion pavement." In the late 1970s, a United Nations Study estimated that 40 percent of Africa's non-desert land was at risk of desertification, as was 32 percent of Asia's and 19 percent of Latin America's land. More recent studies have estimated the damage to the various major types of dryland: rangeland, rainfed cropland and irrigated lands. The total area involved is more than 3 billion hectares, almost one quarter of the earth's land surface. Of these, 60 percent of the rangelands and rainfed cropland are moderately to very severely desertified, as are 30 percent of the irrigated lands. The degrees of damage counted in these categories range from a significant loss of production potential to a total—and sometimes permanent—loss. (See Chapter 5, "Forests and Rangelands": Condition of Rangelands; Chapter 4, "Food and Agriculture": Expanding the Cropland Base; and Part IV, Table 6.3.)

Among the types of soil degradation included in the process of desertification, erosion is one of the most widespread, though it is certainly not limited to arid and semi-arid regions. Depending on local conditions, soil loss and new soil formation are approximately in balance at an erosion rate of about 0.5 to 2.0 metric tons per hectare per year. But agricultural activity, especially on steep slopes, pushes the erosion rate manyfold higher. As expanding populations in many countries push the poorest of the poor farther and farther up steep hillsides, erosion intensifies accordingly. For example, in Nigeria, test plots planted in cassava lost soil at the rate of three metric tons per hectare per year on nearly flat land. On a 5-percent slope the rate jumped to 87 tons, and on a 15-percent slope it rose to 221 tons, a rate that would remove all the topsoil in a decade. The lost soil may be carried away by wind or water. Scientists in Hawaii can tell when spring plowing begins in China because they see the dust over the Pacific. Water-borne erosion can be equally dramatic: China's Huang River is the most sediment-laden in the world. In some stretches it is about 50 percent silt by weight—just under the level classified as liquid mud. (See Chapter 4, "Food and Agriculture": Focus on: Erosion; and Part IV, Table 5.)

Because erosion is so dependent on site-specific conditions, and because it is often studied where conditions are worst, national rates have to be treated with great caution. Nonetheless, they suggest the dimensions of a severe problem. Haiti and Nepal are familiar examples of extreme erosion, but there are many others. In Guatemala 40 percent of the land's productive capacity has been lost to erosion. In Turkey 75 percent of the land is affected, more than 50 percent of it severely. In India 13 million hectares are eroded by wind and 74 million by water, an astonishing one-quarter of the country's land area.

One reason erosion is so difficult to control is that many of its most costly impacts occur miles from the eroding field. In the United States, for example, the annual *off-site* costs of erosion are estimated at $6 billion in damage to fish and coral reefs, loss of hydropower potential, loss of storage capacity in reservoirs, and need for dredging of rivers and harbors. (See Chapter 4, "Food and Agriculture": Focus on: Erosion.)

Like erosion, the salinization and waterlogging that result from poorly managed irrigation can permanently destroy an area's agricultural potential. Though irrigation is perhaps the single most effective way to increase crop yields, it is a demanding technology that requires constant maintenance, sophisticated management, and the construction of expensive drainage systems in order to avoid severe environmental damage. Irrigation failures have a history that stretches back to the Mesopotamians, but they still claim large areas of prime agricultural land each year. As with other types of soil degradation, exact data do not exist, but worldwide, salinization is believed to be forcing as much land to be abandoned as is being newly irrigated. Technological sophistication is no protection: in the United States 20–25 percent of irrigated land is believed to be affected. And since the typical cost of irrigation systems is $1,000–2,000 per hectare (and sometimes much more) the costs of salinization are substantial, even on the scale of national budgets. (See Chapter 8, "Freshwater": Focus on: Irrigation; and Chapter 4, "Food and Agriculture": Irrigation.)

The precise sequence of events in soil degradation depends on the local environment, but the underlying cause is nearly always the same: greater human pressure on a fragile environment. Whether the principal local cause is the destruction of trees and shrubs in the search for fuelwood, the introduction of dryland agriculture to grow more food, poorly managed irrigation, or the overstocking of range to meet increased demand for meat and other livestock products, the challenge that must ultimately be met is to find ways to meet the needs of growing populations without destroying the resource base on which they depend. (See Chapter 5, "Forests and Rangelands": Table 5.13.)

RELATING POPULATION AND RESOURCES

The growing world population poses huge challenges to sustainable management of the Earth's natural resources—its forests, soils, fisheries, and terrestrial species. In many regions these systems are already showing the signs of heavy human pressure. Yet by the year 2100 the planet's population will likely more than double. (See Chapter 2, "Population": Long-Range Projections.)

The relationship between population and the condition of natural resources is not a simple one. Capital investment can offset the effects of large numbers of additional people living on a fixed resource base. So can scientific discoveries and new technologies. The essentials for successful management under growing stress are knowledge, political will, and money. All of these are in short supply, especially in the developing world where 95 percent of the population growth in the next 70 years will occur. There, the grim reality of poverty makes calculations of what is possible of merely theoretical interest.

Even in low-income countries, labor devoted to soil conservation, afforestation, or irrigation can build the resource base to support a larger population. Sometimes fewer people are not better than more. One study has shown that the rural exodus from the Himalayan foothills, rather than lightening the load on a fragile environment, led to an unexpected *decline* in rural productivity, apparently because the women, children, and old people left behind were less able to maintain the area's intricate and vital soil terraces. In the vast majority of cases, however, the general rule holds: more people, especially more impoverished people, make the task of conserving already stressed resources all the more difficult. (See Chapter 2, "Population": Population and Resources.)

Among the few available measures of the balance between population and the resource base, "carrying capacity" is a potentially useful concept. But as yet it can not be accurately defined, much less measured. A study by the U.N. Food and Agriculture Organization (FAO), *Potential Population Supporting Capacities of Lands in the Developing World*, attempted to estimate the carrying capacities of 117 developing nations. The study relates soil types and climate factors to varying levels of agricultural investment in order to calculate the theoretical number of people a given country might be able to feed. Despite the sophistication and sheer magnitude of this study, a look at the number of assumptions that had to be made makes clear that the answers are no more than rough approximations. (See Chapter 4, "Food and Agriculture": Box 4.2.)

Another indicator linking resource condition to its degree of human exploitation is per capita yield. Here too, there are many pitfalls. Consider marine fisheries as an example. For two decades (1950–1970) the total world fish catch rose at a steady 7 percent per year, three times as fast as population growth, yielding a steady per capita increase. The catch dropped dramatically in 1971–72 with the crash of the Peruvian anchovy fishery. Growth resumed slowly, and through the 1970s grew at 1–2 percent annually—slightly less than the population growth rate—showing the beginning of what appeared to be a steady decline in per capita yield.

A closer look shows that the resource trend is much more complicated. For example, the fall in yield in the middle and late 1970s reflected not only the condition of the resource, but also the amount of human effort in fishing, which dropped following the bad years of the early 1970s. The tiny 0.2 percent increase between 1982 and 1983 was due in part to the negative effects of water temperature changes caused by the El Niño current in 1983. In fact, although final data are not yet available as this edition goes to press, preliminary indications are that the 1984 catch topped 80 million tons for the first time in history, with an increase over 1983 of as much as 8 percent, thereby breaking, at least for one year, the "trend" in per capita decline. (See Chapter 9, "Oceans and Coasts": The Marine Fisheries Harvest, and Table 9.1.)

Regional fisheries data make the picture all the more confusing. In the decade 1973–1983 some harvests increased as much as 1,000 percent, while others nearly disappeared. Some of these fisheries were just beginning to be exploited, others were recovering from—or *not* recovering from—earlier over-exploitation, and still others were being fished, at least for the moment, near the peak of their sustainable yield. (See Chapter 9, "Oceans and Coasts": Box 9.1; and Part IV, Table 10.2.)

While one cannot generalize from the fisheries to other resources, some of the implications of these data *are* more broadly applicable: beware global aggregates; trends may be treacherous; in any large scale system involving both biological phenomena and human activity, more forces are usually at work than any single indicator can account for; and biological resources *can* be over-exploited to the point of collapse, sometimes permanently.

While the relationship of population growth to resources is complex, some of the implications for governments are straightforward. More people means greater need for basic services—housing, education, health care and a job. Kenya's population is growing at 4.1 percent per year—the world's fastest rate. Between 1975–1980 Kenya devoted one-third of total government spending to education, health, rural water supply, and urban housing. If current fertility rates continue, the country will have to spend almost nine times as much between 2015–20 just to maintain current standards. Eleven million new jobs will have to be created by 2000, beyond those needed to cope with present unemployment and underemployment. Clearly, accommodating a rapidly expanding population demands rapid national economic growth, but much of this growth will not be sustainable, and thus not successful, unless it is grounded on sound resource management. (See Chapter 2, "Population": Box 2.2.)

Some of the challenges facing governments are breathtaking: by 2025, the projected working-age population in the developing countries alone will be larger than the world's present population. Finding jobs for these 5 billion people will be all the harder in a world where modern technology requires more literacy and education, and displaces more labor than ever before. (See Chapter 2, "Population": Age Distribution and the Labor Force.)

On the other hand, modern technology—both new methods of contraception and means of communication via television and satellite—offers the possibility of limiting fertility more rapidly than ever before. And because fertility rates affect future generations as well as the present one, they hold the key to the world's demographic future.

A young woman today who bears three children instead of the six her mother may have borne will have 27 great-grandchildren instead of 216 (assuming her children and grandchildren have the same fertility rate). Thus, filling the large unmet need for contraception is certainly one of the investments that stands to have the greatest impact on the future condition of the Earth's resources. (See Chapter 2, "Population": Stabilization, and Focus on: Fertility.)

AFRICA

Africa is a special case. Nowhere else on the planet are resource trends so discouraging, the outlook so dire. Despite billions of dollars of external assistance, and thousands upon thousands of development projects and foreign experts, conditions have steadily worsened. Prominent among the reasons are rapid population growth, a difficult and often fragile environment, and resource mismanagement—sometimes due to lack of attention, and sometimes to policies and development strategies unsuited to local conditions.

The continent has the world's fastest population growth rate—3.01 percent per year, compared to about 1.67 percent for the world as a whole. Africa is adding people 10 times as fast as Europe, and more than three times as fast as the United States or the Soviet Union. At this rate, the number that must be fed, housed, educated, provided with health care, and employed will double in a scant 23 years. If current trends continue, Nigeria will eventually become the world's third most populous nation, with a population about equal to that of the entire continent today. (See Chapter 2, "Population": Population Growth by Region, Stabilization; and Part IV, Table 2.1.)

Why is growth so rapid? One answer was provided by the World Fertility Survey, conducted between 1974 and 1982. Women were asked how many children they would have "if they could choose exactly." The results revealed a substantial unmet need for contraception. In Latin America, for example, women would have two or three fewer children if they could choose. Only in sub-Saharan Africa did women seem to want as many children as they were having—a continent-wide average of 6.43 per woman. Again the question is: why? The answers are hidden in an intricate web of social, cultural and economic factors ranging from women's low status to the often vital labor provided by children. (See Chapter 2, "Population:" Unmet Need for Contraception, Figure 2.8, and Box 2.2.)

These numbing population statistics translate into about 1 million more mouths to feed every three weeks—the time it can take a planted seed to germinate. This burden must be borne on a continent in which more than 80 percent of the soils have fertility limitations, where 47 percent of the land is too dry for rain-fed agriculture, and where an area larger than the United States is ruled by the tsetse fly, whose bite spreads incurable trypanosomiasis (sleeping sickness) to people and livestock. It is not surprising, then, that in the 10 years following the 1974 World Food Conference, Africa was the only region of the developing world that did not meet the projected goal of a 2.6 percent annual increase in agricultural production. Worse, it combined less-than-expected production with higher-than-projected population growth. In only five of the 41 sub-Saharan nations did production growth exceed population growth. In many of the others, per capita food production fell by 20 percent or more, so that even before the current drought, one quarter of the total sub-Saharan population had become dependent on food imports. (See Chapter 4, "Food and Agriculture": Production and Consumption, Agriculture in Africa, Table 4.9; and Part IV, Table 5.3.)

Large parts of Africa are arid and semi-arid, areas where rainfall is sparse and, more important, highly variable. Average rainfall varies from year to year by a huge 30–40 percent, so that "normal" precipitation means something quite different from what it means in the temperate zones. What *is* normal are multiyear, recurrent droughts—of which there have already been three in this century. (See Chapter 8, "Freshwater": Variability of Rainfall, Figure 8.5, and Box 8.1.)

The traditional African nomadic way of life was a successful solution to this environment. Though nomadism provided only a subsistence-level existence, and was disparaged by foreign experts, modern science is just beginning to understand how well-suited the system is to its environment. Recent studies are finding that the productivity of Sahelian animal husbandry (measured in animal protein per unit area) equals or exceeds that of ranches in comparable rainfall regions of the United States and Australia. This realization comes, however, after two decades of foreign assistance and domestic policies aimed at replacing pastoralism with settled agriculture, largely through the digging of wells. Today the worst rangeland conditions in the Sahel are found near year-round water supplies and where pastoral and agricultural land uses coexist. Large homogeneous herds of cattle were another misguided innovation. The traditional smaller mixed herds made much better use of the scarce resources, with camels, sheep and goats eating vegetation cattle do not touch. (See Chapter 5, "Forests and Rangelands": Condition of Rangelands and Development Assistance and Range Management, Table 5.13, and Box 5.1.)

Africa's agricultural production can certainly be boosted, but for various reasons many of the modern approaches are of limited applicability. For example, Africa, of all the continents, has the lowest potential for irrigation. Except in South Africa and along the Nile River, unfavorable topography, low groundwater reserves, insufficient trained managers, and inadequate funds severely limit its prospects. Only Oceania, among the world's regions, has as low a percentage of irrigated cropland. (See "Food and Agriculture": Irrigation, Table 4.6; and Part IV, Table 5.2.)

Closely tied to its agricultural problems is Africa's fuelwood crisis. Many African countries depend on fuelwood and other forms of biomass for more than 90 percent of their energy. Even in oil-rich Nigeria, fuelwood is the primary fuel. Today nearly 40 percent of all Africans must cope with a deficit or an acute scarcity of fuelwood. By 2000, the number is projected to have more than doubled and the proportion to reach 60 percent. In rural areas the fuelwood shortage means more erosion, lower soil fertility, less forage for livestock, and growing human suffering. The environmental impacts are felt in urban areas as well. As fuelwood and the charcoal made from it are trucked in to supply urban residents, an expanding "ring of desolation" surrounds the cities. (See Chapter 7, "Energy": Biomass Fuels, Focus on: Fuelwood Scarcity, and Table 7.8.)

Though the immediate outlook is not promising, Africa's resource problems should not prove insurmountable. However governments' policies, and, where policies are favorable, governments' weak capacities to act, remain major hurdles. In 1985, Julius Nyerere, President of Tanzania, succinctly described where things now stand for many governments: "Until the last few years, Africa regarded environmental concern as an American and European matter. Indeed there was a tendency to believe that talk of the environment was part of a conspiracy to prevent modern development on our continent! Now we have reached the stage of recognizing that environmental concern and development have to be linked together if the latter is to be real and permanent. The question is how to do this." For a great many of these problems, the "how" is still unclear. Basic data are unavailable, properly focused research is sparse, government institutions are weak, and international assistance, though well-intentioned, is often misdirected. Still, there is reason for hope. Governments and a growing number of citizens' groups are beginning to understand and to act upon the linkages between Africa's unique environment and its development prospects. (See Chapter 11, "Policies and Institutions": Assessment, Management: The Capacity to Act, and The Larger Context.)

World Resource Reviews **Part II**

2. Population

Because population, availability of resources, quality of the environment and prospects for economic growth are inextricably linked, understanding the dynamics of world population growth is the logical starting point for a study of the resources that sustain life on Earth.

CONDITIONS AND TRENDS

POPULATION GROWTH TO THE PRESENT

The growth of the world population may be the greatest of all the changes of the 20th Century. Although the rate of growth has fluctuated, unprecedented population growth has been an enduring characteristic throughout wars, famines, economic boom and bust, technological advances, and dramatic shifts in the global power structure.

At the beginning of the century there were about 1.6 billion people in the world. Initially the growth rates were low, averaging about 0.8 percent per year for the first half of the century (1). By mid-century there were 2.5 billion people on Earth, and by 1985 this figure had nearly doubled to 4.8 billion (2).

To put that figure into perspective, it helps to look back at the growth of human numbers since mankind's appearance on earth. It took the human family millions of years—until around 1800—to reach the one billion mark. (See Figure 2.1.) It only took 130 more years to reach the second billion, in about 1930. The third billion was added by about 1960, and the fourth in 1975 (3).

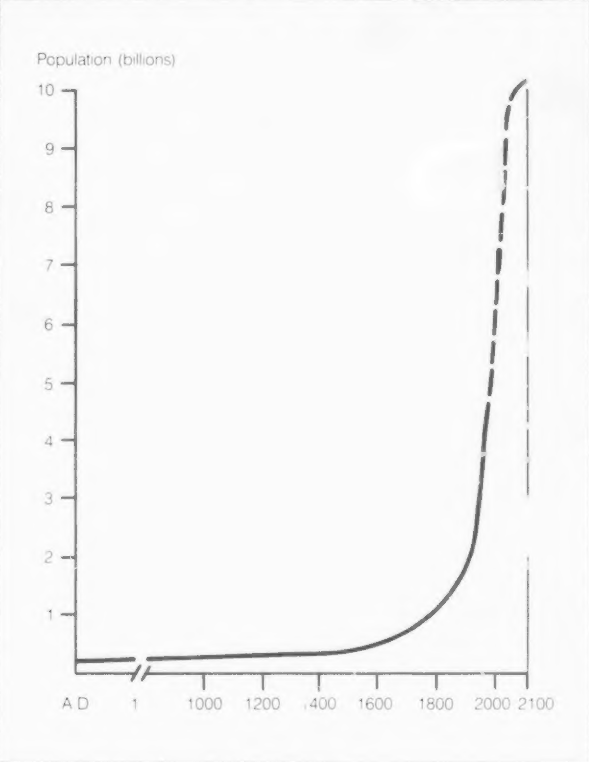
Early in the second half of the century the population growth rate accelerated until the year 1970 when it reached what might have been an all-time historical high of 2.06 percent per year. Stated differently, the rate of growth of the world population increased from about 2 percent *per thousand years* in the prehistoric past, to about 2 percent *per year* in 1965–70.

The early 1970s marked an historic turning point. For the first time in human history, the growth rate began to decline, and this trend has continued. However, because of the immense momentum built up in the past, the continuing decline in mortality rates, and the high absolute numbers involved, more people are still being added to the Earth's total each year.

During 1985, when the global population was estimated at about 4.8 billion, approximately 80 million people were added to the human race. This is equivalent to the total of the current populations of New York City, Moscow, London, Beijing (Peking), Mexico City, and Rio de Janeiro. If a decline had not begun, the annual increment of global population would be even higher. As it is, the annual increment for the period 1995–2000 is projected to be about 90 million (4).

What is "rapid" population growth? The term generally refers to annual increases of about 2 percent or more (5), but there is no absolute threshold. (A population growing

Figure 2.1 Past and Projected World Population, A.D. 1–2100



Source: World Bank, 1984, Reference 18, p. 3.

at 2 percent a year will double in 35 years; at 3 percent in 23 years, and at 4 percent a year it will double in 17.5 years.) In 1985 the world's highest rate of population growth—4.1 percent—occurred in Kenya. The growth rates of India and Indonesia, which are more than 2 percent, would be classed as "rapid," while that of China (1.17 percent, a doubling time of 60 years) would not.

Since the global population numbers in the billions, even a small rate of increase or "compound interest rate" can produce considerable yearly increments. Just as some countries' national debts assume immense proportions because of periodically compiled interest, so too do some countries' populations increase enormously. Working with ten-digit figures, even a small difference in the rate of growth can be very significant.

Growth by Region

Growth occurs at very different rates in different parts of the world. (See Figure 2.2.) The developed world grew from 0.8 billion in 1950 to 1.2 billion in 1985. In the same period, the population of the Third World increased from 1.7 billion to 3.7 billion (6,7).

Differences between regions were significant. The greatest absolute decline in growth rate occurred in East Asia, and most of that was accounted for by China. At the beginning of the period, Latin America was the fastest-growing region, while by 1985 Africa was the leader. The regional shares of the global population in 1950 and 1985 can be seen in Table 2.1. Since 1950 there has been some shifting of the rank order, with Africa overtaking Europe to become the world's third most-populous region.

In terms of sheer numbers, China and India dwarfed the others on the list of the world's 12 most populous countries: China, 1.063 billion; India, 761 million; the Soviet Union, 276 million; the United States, 238 million; Indonesia, 165 million; Brazil, 136 million; Japan, 130 million; Pakistan, 102 million; Bangladesh, 101 million; Nigeria, 95 million; Mexico, 79 million; and the Federal Republic of Germany, 61 million.

POPULATION AND RESOURCES

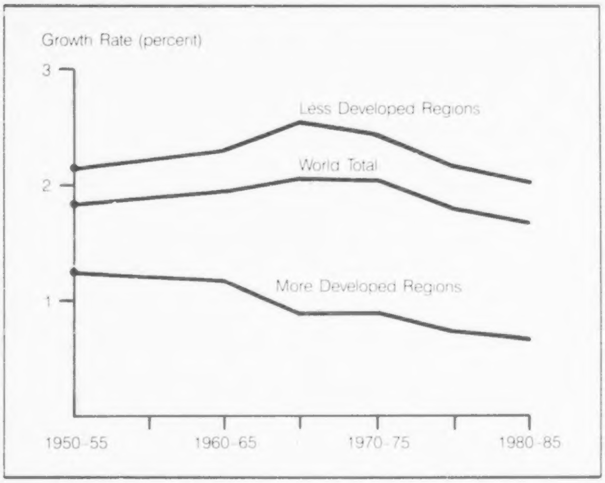
Population growth subjects natural resources and the environment to increased pressure, but the relationship is not a simple one. Where land and other resources are already under stress—in absolute terms or because of poor management—the impact of additional people can be direct and strongly negative. Where resources are more ample, or where economic investment buffers the impact of more people, the connection becomes much more complicated.

One commonly used indicator of the link between population and resources is population density. However, the number of people per square kilometer, though easily measured, is not very revealing. Clearly, simple Malthusian equations are not equally at work in Singapore with a 1975 population density of 53 people per hectare and Senegal with less than one person per hectare, when life expectancy at birth in 1980 was 72 years in Singapore, and only 44 years in Senegal. Nor does the contrast between the 1985 population densities of the Netherlands, 335 per square kilometer, and Norway, 13 per square kilometer, reveal much about the two countries. Much of the land in the Netherlands was dredged out of the sea, and nearly every square inch is put to use, while most of Norway's land is taken up by largely uninhabited mountains.

The concept of carrying capacity is another approach used to link population with the natural resource base (8). Though much used by biologists and ecologists, the term has not yet been well defined. Since the adoption of a recommendation at the 1974 World Population Conference in Bucharest, a number of studies have been launched to understand "the complex relations among the problems of population, resources, environment, and development, and to promote a unified analytical approach to the study of these interrelationships" (9). But progress toward this lofty goal is still limited.

The United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and the Biosphere (MAB) Program has concentrated on the study of these relationships in island ecosystems, particularly Fiji and Barbados, where methodological problems can be more easily solved. Other work is currently underway in the

Figure 2.2 Average Annual Population Growth Rates in More Developed and Less Developed Regions, 1950–85



Note: More developed regions include Europe, North America, Australia, Japan, New Zealand, and USSR. Less developed regions include Africa, Asia, Latin America, and Oceania.
Source: Department of International Economic and Social Affairs, 1985, Reference 2

Himalayan Mountains where the steep slopes accentuate the relationships among population, soil erosion, and downstream flooding. These studies shed light on simplistic notions about the harmful effect of dense populations on natural systems. For example, the movement toward cities from the Himalayan foothills led to an unexpected decline in rural productivity as those left behind (the old, the women, and the young) were less able to maintain vital soil conservation terraces (10).

Most such studies have as their purpose a better understanding of these relationships to aid improved national planning (11). The most ambitious such endeavor was undertaken following the first "Sahelian drought," the massive food shortages in West Africa in the early 1970s, by the U.N. Food and Agriculture Organization (FAO), the U.N. Fund for Population Activities (UNFPA), and the International Institute for Applied Systems Analysis (IIASA). The study investigated the degree to which natural productivity (chiefly determined by climate, latitude, soil type, and similar parameters) can be augmented by mechanization, irrigation, fertilizers, pesticides, and the like, to reach production levels sufficient to maintain present and projected populations. (See Chapter 4, "Food and Agriculture," Box 4.2, "Land, Food, and People.")

Table 2.1 Share of World Population by Region, 1950 and 1985

(population in millions)

Region	1950 (millions)	Percent of World Total	1985 (millions)	Percent of World Total
Africa	222	8.9	553	11.4
Latin America	165	6.6	406	8.4
North America	166	6.6	263	5.4
East Asia	571	22.8	1,252	25.9
South Asia	695	27.8	1,572	32.5
Europe	392	15.7	492	10.2
Oceania	113	4.5	25	0.5
USSR	180	7.1	278	5.7

Source: Department of International Economic and Social Affairs, 1985, Reference 2

A third approach to the relationship of population to natural resources looks at per capita production as the principal indicator. Some studies show that world grain production per capita peaked in the 1970s, as did fish and beef production; and that while, in the case of grain, increased yields could still be obtained through increased use of fertilizer, there was a declining response per unit of input (12).

None of these approaches, however, yet provides an analytically sound method of studying these vast and complex relationships. More research and new ideas are badly needed.

PROJECTIONS OF THE FUTURE

Future world population is also a subject of intense research and debate (13,14). Its main components are past and present fertility and mortality rates and international migration figures. For the near term, population projections are relatively secure, because the next generation and the parents of the generation after next have already been born.

However, projections are not forecasts. They are no more than educated extrapolations of current trends, and even near-term projections rest on numerous assumptions. Moreover, current trends often change rapidly. Even though equipped with the world's best census data, for example, demographers misjudged the size and duration of the postwar baby boom in the United States.

The United Nations Population Division projects country-by-country populations to the year 2025, and regional projections to the year 2100. The World Bank, on the other hand, provides country-by-country projections to the year 2155 (15). The projections from these two United Nations organizations, together with those of the United States Census Bureau, constitute the universe of widely accepted and regularly published projections. For most countries, the differences in the projections over the near term are very slight.

Most of the population figures used in this chapter are taken from the United Nations projections to 2025 published in 1985 (16), and from the United Nations long-range projections published in 1981 (17). These projections are based on adjusted data from the most recent national censuses.

To illustrate the uncertainties, consider the United Nations' 1985 projections. Among the assumptions on which they rest are that unpredictable catastrophes such as wars, famines, and epidemics will not occur. Steady socioeconomic growth and a steadily declining fertility rate were assumed for the developing countries. Life expectancy was assumed to grow by 2.5 years during every five-year period—as it has in many developing countries during recent decades—up to 82.5 years for women and 75 years for men. Adjustments were factored in for developed countries where life expectancy is already high, and for some developing countries (for example, sub-Saharan Africa) where conditions are not conducive to lengthened lifespan.

Analysts further assumed that existing or anticipated government family-planning programs would accelerate fertility decline. Where a decline in fertility was already evident, it was expected to begin slowly, accelerate, and then slow down. Principally because of incomplete knowledge and past abrupt changes, international migration was assumed to cease entirely, except where there is strong evidence to the contrary (for example, between Mexico and the United States). Analysts even ventured to consider "trends and anticipated changes in socioeconomic and cultural values of the society." And finally, four variants—high, medium, low, and constant—were chosen and "crossed" among the assumed levels of fertility, mortality, and migration, to give a wide range of possible futures. Clearly, even relatively short projections are subject to many surprises, especially for the developing countries where very large populations, high birth and death rates, and shifting government policies combine to make the demographic future very difficult to foresee.

LONG-RANGE PROJECTIONS

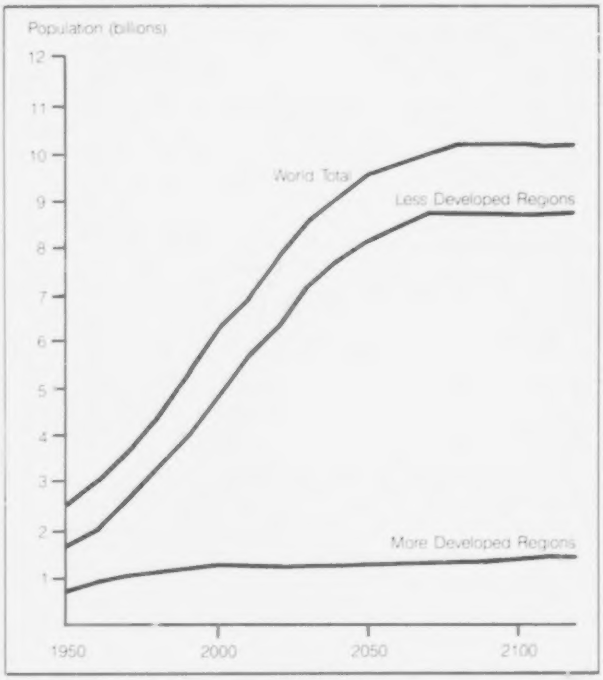
Figure 2.3 provides a graphic illustration of the projected future of the human population to the year 2150, based on the United Nations long-range medium variant projections. By the year 2100, the Earth's population would have more than doubled, with 95 percent of the increase between the years 1980 and 2050 taking place in the Third World. While the population of the developed regions would have grown to 1.4 billion by 2100, that of the developing regions would swell to 8.8 billion.

Considerable shifts would occur among the major regions of the world (see Figure 2.4). Africa would continue its current surge of growth to emerge as the second most populous region of the world. South Asia, where about 1.5 billion people lived in 1980, would be home in 2100 to more than double that number. East Asia, where China exerts the dominant demographic influence, is projected to level off in about the year 2030. The population of Latin America is projected to continue growing, but at decreasing rates. Europe, North America, and the Soviet Union would follow a low-growth pattern throughout the period. Although the cumulative increase in these three more developed regions would be relatively small, it translates into an additional 270 million people, or nearly the present population of the Soviet Union.

Stabilization

Long-term extrapolations that assume rising life expectancy to an eventual maximum and declining fertility that eventually reaches replacement level, project a world population that eventually stabilizes. If fertility drops below replacement level and does not climb back up, as it has to date in several parts of the developed world, eventual world population would slowly decline. The United Nations and the World Bank projections for the dates when net reproduction rates reach 1.0 are shown in Table 2.2.

Figure 2.3 **Population Size for More Developed Regions, Less Developed Regions, and World Total, 1950–2120**



Note: More developed regions include Europe, North America, Australia, Japan, New Zealand, and USSR. Less developed regions include Africa, Asia, Latin America, and Oceania.

Sources:

1. Department of International Economic and Social Affairs, *World Population Prospects as Assessed in 1980, Population Studies No. 78* (United Nations, New York, 1980), p. 12.
2. Department of International Economic and Social Affairs, *Long-Range Population Projections of the World and Major Regions, 2025–2150, Five Variants as Assessed in 1980, 1981* (United Nations, New York, 1981).

As with shorter projections, these estimates depend on many underlying assumptions: the more extended the projection, the more tenuous the connection to reality. According to the United Nations medium variant projections, if the net reproduction rate of 1.0 (replacement level fertility) is reached by the year 2035, the global population would stabilize by the year 2100 at 10.2 billion. The World Bank's estimated hypothetical stationary population is 11.2 billion. Although U.N. forecasters consider their medium variant projection to be the most plausible, four other variants were prepared to provide a reasonable range. The projections for the year 2100 vary from a low of 7.2 billion to a high of 14.9 billion.

The most illuminating feature of such estimates is the impact of what happens now and in the near future, especially to fertility. Fertility declines have more influence than do drops in mortality because high fertility means many more people added over generations. A baby girl who grows up to have 3 children instead of 6, will have 27 great-grandchildren rather than 216 (18). If unexpected changes in fertility rates delay or advance the projected stabilization date, the consequences for eventual population levels are immense. A 20-year delay in a replacement level date of 2025 means an eventual population 2.8 billion larger. A 20-year advance means 2.2 billion people less. The difference over this short 40-year span is more than the present total world population (19).

The World Bank's country-by-country projections to the year 2100, however speculative, provide tantalizing glimpses of future possibilities. Perhaps the most surprising projection is for the west African country of Nigeria. Few are aware that Nigeria may eventually become the world's third largest country. According to these projections, by the time Nigeria's fast-growing population finally stabilizes, probably after the year 2100, it may reach half a billion. Only China and India are projected to have larger populations by the time they stabilize; 1.5 billion for China and 1.7 billion for India.

MORTALITY

Life Expectancy

Life expectancy, the number of years a typical individual can expect to live, given current levels of mortality, has increased greatly since 1950, and is expected to improve further in the future.

On a global level, life expectancy increased from 45.8 years in 1950–55 to 58.9 years in 1980–85, and according to the U.N. projections is expected to reach 70 by the year 2025. Present life expectancy in the more developed countries averaged 73 in 1980–85, and in the less developed regions it was 56.6; the estimates for 2025 are 77.2 and 68.9, respectively.

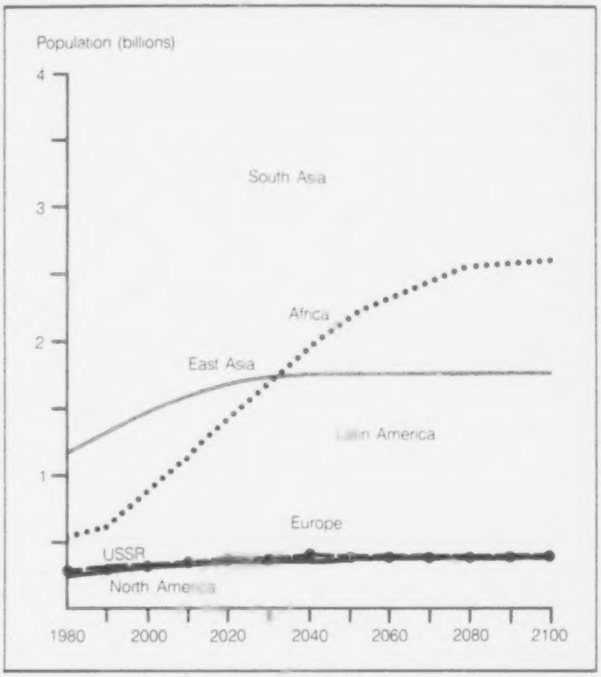
In countries where life expectancy is already high and may be bumping up against some biologically determined ceiling, the rate of improvement has slowed. For example, in Iceland, which had the world's highest life expectancy of 77.6 years in 1980–85, only a slight increase, to 78.2 years, is projected by the period 2020–25. In Sudan, an increase of 28.8 years is projected during the same time span.

Although in most countries women have a longer life expectancy than men, the opposite is true in some countries of South Asia. Countries where female life expectancy is lower include Afghanistan, Bangladesh, India, the Islamic Republic of Iran, Nepal, and Pakistan. The relatively low status and high fertility of women in these countries may be contributing factors (20).

Economic Well-Being

In general, mortality and national income are inversely related, but there are many variations and some exceptions to this rule. The countries of South Asia and sub-Saharan Africa tend to have the lowest incomes and the highest mortality rates, while the wealthier countries of Latin America and East Asia have lower mortality. However, as Figure 2.5 shows, virtually all developing countries showed longer life expectancy over the decade 1972–82, even where per capita income did not grow significantly. And some countries—China, Sri Lanka, and Costa Rica, for example—do far better than the average at their income level. The key factors are access to health care, a national emphasis on the provision of this and other basic human services, and a relatively egalitarian economic structure (21).

Figure 2.4 Projected Total Population of Major Regions, 1980–2100, as Assessed in 1980



Source: United Nations Secretariat, *Population Bulletin of the United Nations*, No. 14 (United Nations, New York, 1983), p. 24

Large differences in mortality exist not only between rich and poor countries, but also between different social strata within countries (22). In France, the probability of death for males aged 55–65 during the period 1966–81 was three times higher for unskilled workers than for men working in senior management and in the professions. In England and Wales, there are significant differences in life expectancy between socio-economic groups and social classes. In the United States, infant mortality rates have long been significantly higher for the non-white population.

Infant Mortality Rates

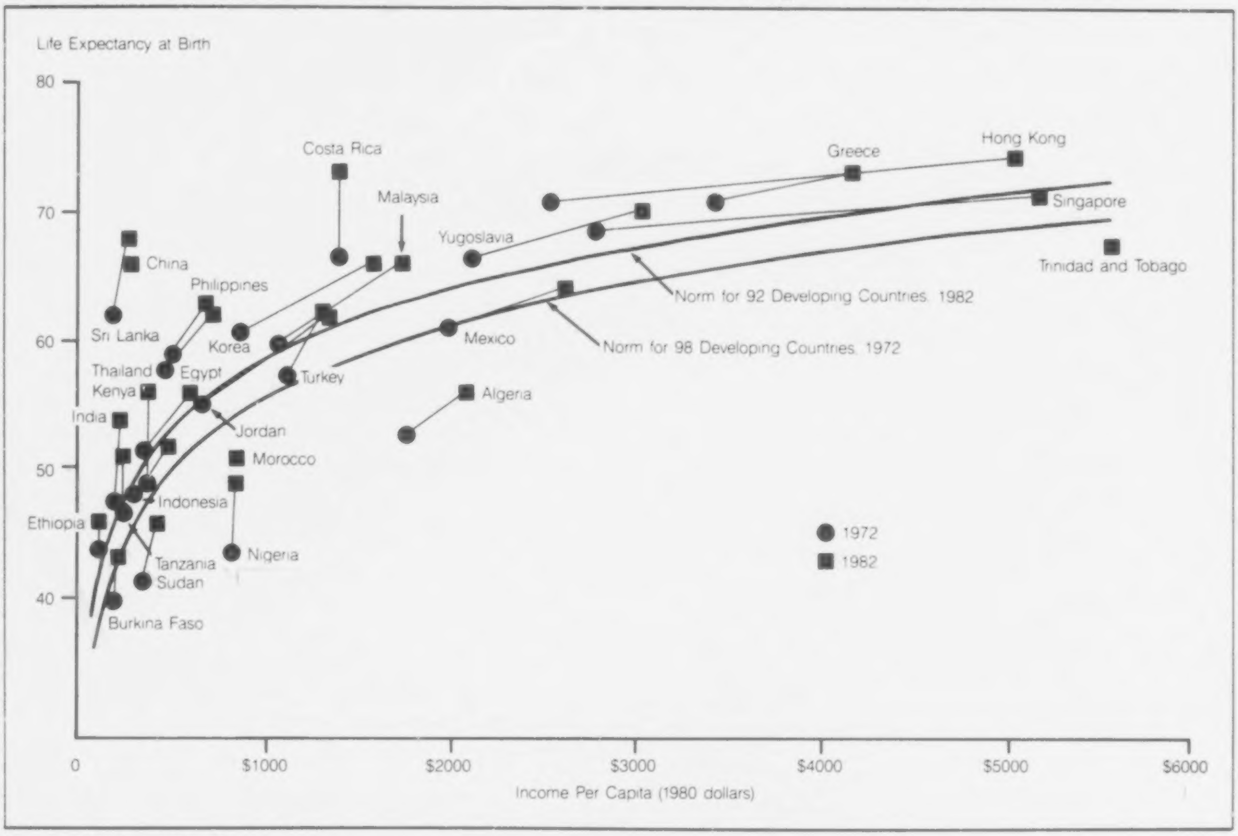
Much of the improvement in mortality rates can be attributed to the fact that more infants are surviving the

Table 2.2 Year in Which Net Reproduction Rate (NRR) Reaches 1

United Nations Projection		World Bank Projection	
East Asia	1990	USSR	2000
North America	1995	North America	2010
Europe	2020	Europe	2010
South Asia	2020	Latin America	2030
USSR	2030	Oceania	2035
Oceania	2035	Asia	2045
Latin America	2040	Africa	2045
Africa	2045		

Source: United Nations Secretariat, "Long Range Global Projections, as Assessed in 1980," *Population Bulletin of the United Nations*, No. 14 (1982) p. 20

Figure 2.5 Life Expectancy in Relation to Income in Developing Countries, 1972 and 1982



Source: World Bank, 1984, Reference 18.

precarious first year of life. Still, conditions in some countries are so difficult that more than one in ten babies dies in its first twelve months. (See Figure 2.6.) Recently, the rate of improvement in infant and child mortality has slowed significantly. (See "Recent Developments," below.)

In general, infant mortality rates serve as indicators of a country's socio-economic condition. Among the factors influencing infant and child mortality are: the mother's age (younger and older mothers are more liable to lose their babies), length of interval between births (longer intervals are healthier), and the education of the parents (lower infant mortality rates are associated with educated parents). Also, first babies born to very young mothers and high-order births (such as the sixth or seventh child) are more vulnerable (23).

THE DEMOGRAPHIC TRANSITION

The developed countries have already made the demographic transition from a high mortality status to a low mortality-low fertility condition, while the developing countries are in the process of doing so. The demographic history of a country like Sweden (See Box 2.1) illustrates the differences between the typical road traveled in the 18th and 19th Centuries, and that facing developing countries today. In most of today's developed countries, mortality declined slowly, principally because of improved living standards: this was still the period before medical achievements had made much of an impact. During this period fertility rates were also low. As population grew, emigration relieved the pressure. In one 90-year period, 45 percent of the increase in the population of the British Isles emigrated (24).

For today's developing countries, the situation is quite different. A transition that took more than a hundred years in a country like Sweden is happening in the space of a few decades in a country like Sudan. Mortality drops rapidly, principally in response to immunization, antibiotics, control of malaria, and other forces of modern medicine. As Figure 2.7 illustrates, fertility rates are far higher than those faced earlier by the developed countries. Emigration provides few opportunities. (See Table 2.3.) Moreover, since the initial population base is usually quite large, annual increments can be very substantial. Modern society requires more literacy and education while technology displaces more labor than before—both forces that increase the demands on government services.

On the other hand, modern communication and methods of contraception make it possible to greatly speed the control of fertility.

Age Distribution and the Labor Force

The world's population is getting older. The median age has increased slightly from 22.9 years in 1950 to 23.3 in 1985. By the year 2025, the median age will exceed 30 (25). The trend from 1980 through 2100 shows a relatively rapid increase in the portion of the population aged 60 and over. In the developing countries, their numbers are projected to increase from 214 million in 1950 to more than a billion by 2025 (26).

The 0–14 age group, on the other hand, is projected to experience a relative decline, although the absolute increase in the number of youth will challenge the educational institutions of tomorrow. In the less developed countries, an estimated 500 million additional people are expected to have entered the labor market by the turn of the century (27). By the year 2025, the working age population in the developing countries alone will be larger than the world's current population (28).

Providing jobs for this vast new work force will demand far-reaching changes in most governments' investment strategies, systems of land tenure, and tax and pricing policies (29).

FOCUS ON: FERTILITY

Explaining fertility decline has proved to be even more difficult than recording it. What are the determinants of fertility change? What factors are at work to determine the number of children people have?

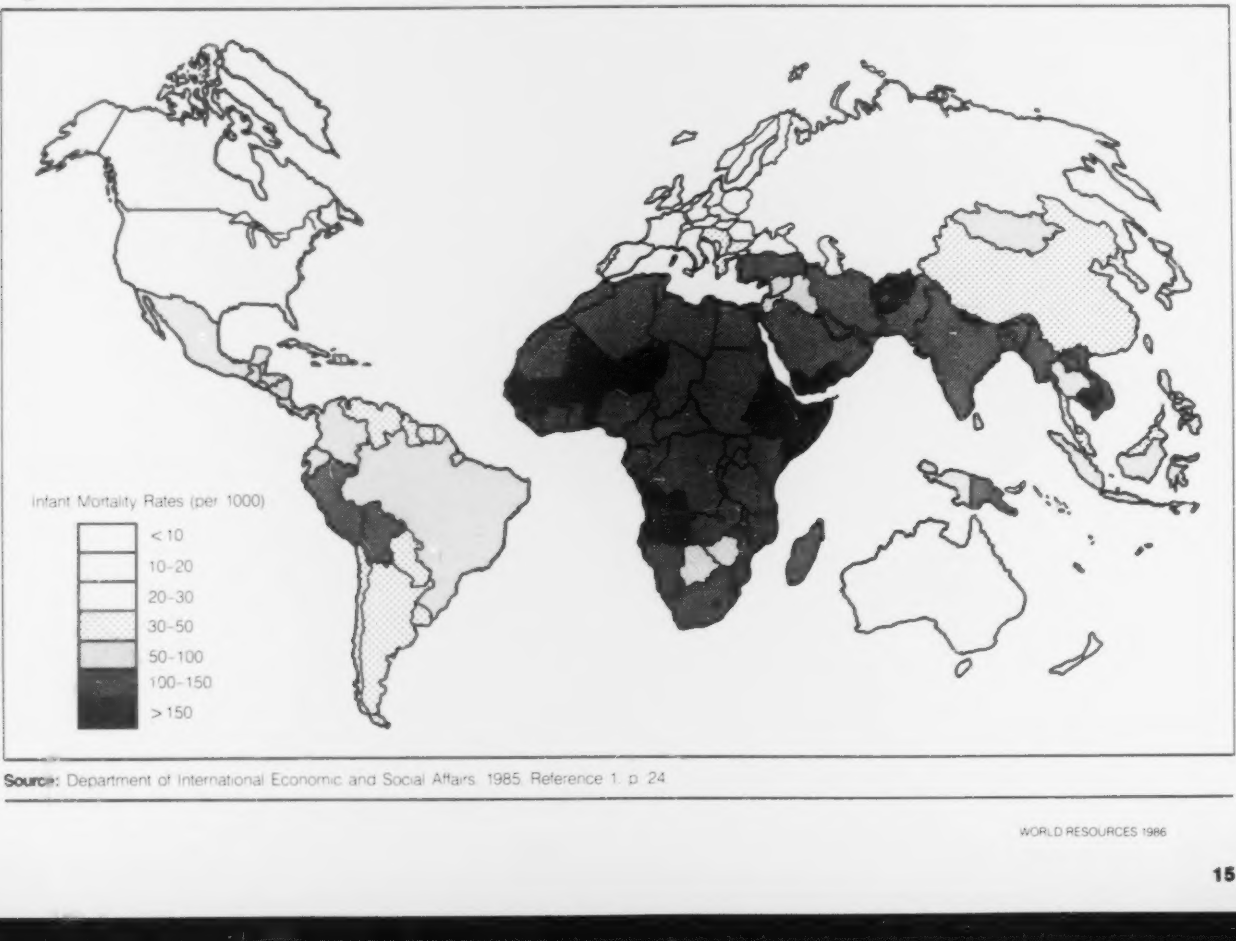
In the world as a whole, the total fertility rate (TFR), the average number of children a woman bears in the course of her child-bearing years, declined from 4.99 in 1950–55 to 3.90 in 1975–80. The TFR is projected to decline to 2.32 by 2020–25 (30).

By region, East Asia led the decline in fertility, dropping from 2.44 in 1950–55 to 1.9 in 1975–80, with a projected continued decrease to 1.13 in 2020–25. Latin America and South Asia have also experienced noteworthy fertility declines. In Africa, on the other hand, there was little change in the fertility rate between the years 1950 and 1980. Yet the United Nations projects a rapid decline in the future.

North America and Europe have seen steep fertility declines, but rates are projected to eventually pick up again, slightly, to reach replacement levels. The Soviet Union is projected to continue its slow decline, eventually reaching a level just above that of North America.

During the period of the World Fertility Survey, 1974 to 1982, fertility was highest in the Middle East and sub-Saharan Africa, with an average of seven children per

Figure 2.6 Estimated Infant Mortality Rates, 1975–80



Source: Department of International Economic and Social Affairs. 1985. Reference 1. p. 24

Box 2.1 The Swedish Example

Sweden is unique in having an unbroken series of poulation statistics from the year 1749. These statistics tell the story of how Sweden gradually transformed itself from a poor, developing country with high birth and death rates to a prosperous country with birth and death rates that are among the lowest in the world (1).

FROM 1750 TO 1850

Around the year 1750, Sweden was largely an agrarian society with a rigid, hierarchical class system. The average life expectancy for men was 34.2 years; for women it was 37.6 (2). (In 1980–85 only a few countries had life expectancies below 40 years; they included Sierra Leone, Gambia, and Afghanistan (3).) In the mid-1700s, the Swedish population of about 1.7 million was more or less defenseless against infectious diseases such as smallpox and spotted fever. Dysentery, measles, and whooping cough took heavy tolls. Periods of famine left the population weakened and susceptible to diseases. Some efforts were made to provide organized maternity care and to establish famine relief, but conditions remained difficult. Nevertheless, by the year 1850, the life expectancy for Swedes had increased to 43.5 years for women and 39.4 for men. Infant mortality rates improved steadily. From 1750 to 1850, the population doubled (4).

FROM 1850 TO 1930

Because of a series of advances, including hospital care; vaccination against smallpox; antiseptics; and improved hygiene, sanitation, water supply, and sewage systems, mortality rates fell and the population grew until, by 1900, it was considered a national problem.

A wave of emigration then swept the country, as it had other parts of Europe, and about one out of every five Swedes moved out. Birth rates continued to decrease, and mortality rates decreased even more. The population continued to grow (5).

FROM 1930 ON

At the beginning of the 20th century, Sweden was still a poor country with many social and economic problems. By 1930, housing remained overcrowded, and sanitary and hygienic conditions were poor. Wide disparities existed between social classes, as seen in the infant mortality rates, which ranged from 49 deaths per 1,000 births in low-income families to 14 in high-income groups.

On the positive side, the beginnings of prosperity were seen: an early law had virtually eliminated illiteracy, women enjoyed a relatively high status and joined the labor force in increasing numbers in the 1920s and 1930s, and child labor began to disappear. The cost of raising a child at the time was equivalent to a third of the average income. The birth rate continued to fall.

Traditionally, social security against illness, old age, unemployment, and accidents was supplied by the large, three-generational family, the neighborhood, the parish, and the church. By the 1930s, the nuclear urban family had emerged and the old support net was no longer there. At that time some forms of government social security were introduced, along with a national health insurance scheme, and employer insurance against occupational accidents or diseases.

When Alva and Gunnar Myrdal published their book *Crisis in the Population Issue* in 1934, the basis for the modern Swedish view of population problems was established. "Revolutionary" ideas that were intended to stimulate the birth rate were introduced including maternity welfare, increased maternity benefits, tax incentives, housing allowances, nursery schools, children's health services, free school meals, cheaper educational facilities, and massive information/education campaigns on housing, nutrition, and health. Particularly important was the concept of "voluntary parenthood," meaning that only wanted children need be born.

During the 1940s, more reforms were introduced, such as day care nurseries and kindergartens, loans for newly-married couples, and fewer restrictions on abortions. In 1956, sex education became compulsory (6).

SWEDEN NOW

The population of Sweden grew from 6.4 million in 1940 to 8.3 million in 1985. Immigration from abroad accounted for most of the increase. During decades of prosperity, the total fertility rate fell from 2.22 in 1950–55 to 1.55 in 1980–85, indicating that the average Swedish woman had 1.55 children, too few to allow the replacement of the current generation of Swedes (7).

In 1982, an official survey was authorized to determine why so few children were born (8). The results of the survey indicated:

- More women were obtaining higher levels of education than in the past, thus postponing their childbearing years.
- The more education a woman had, the fewer children she was likely to have.
- More women were in the labor force, and those with higher-status jobs had, as a rule, fewer children than those with lower-status jobs.
- Nearly all women considered having children as one of the meaningful things in life.
- More young Swedish couples lived together without being married, and people were not as likely to have children outside of marriage.
- The use of effective methods of contraception was widespread.
- Finding day-care was a problem for many working women.
- By far the greatest burden of housework, cooking, and shopping was carried by women, including those working full-time who had children. In fact, after women had children they shouldered even more household duties.

Sweden's growth rate, 0.01 in 1980–85, is projected to be -0.14 in the period 1985-90. Life expectancy, 75.8 in 1980–85, is one of the highest in the world. The infant mortality rate is one of the lowest in the world, at seven infant deaths per 1,000 births (9).

This is the pattern that has been repeated, with many variations, throughout the developed world. The road from high to low mortality in the developing countries will be a much shorter, and rockier, one.

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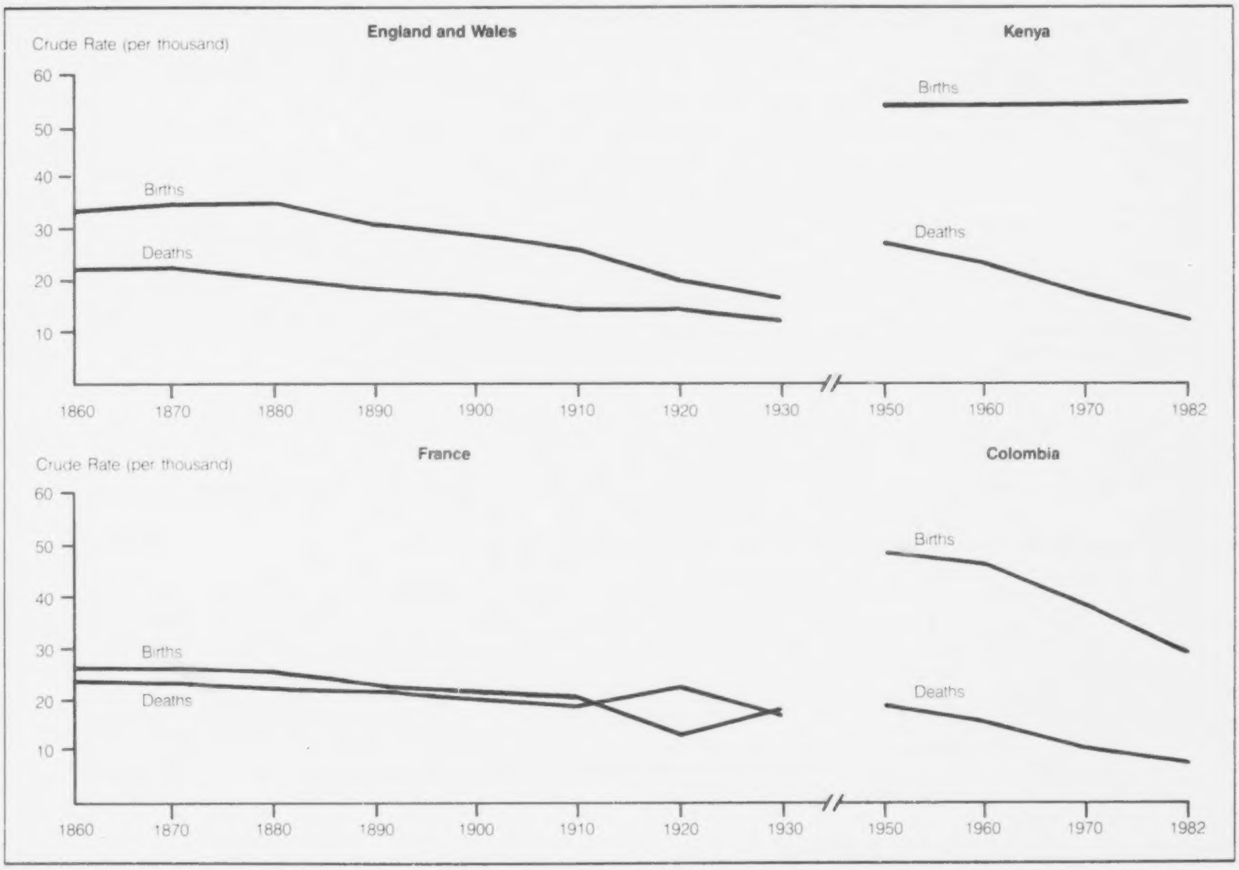
8. *Op. cit.* 4.
9. *Op. cit.* 3.

woman. (See Box 2.2.) The average number of children per woman was six in North Africa and 4.5 in Asia and the developing countries of Central and South America (31).

Some of the variables suggested as responsible for fertility decline include (32):

- The spread of family planning programs and availability of contraceptives
- Decreases in childrens' contribution to the family labor force and family income
- Less need for children as insurance against old age or accidents
- Higher cost of raising and educating children
- More education for women
- Urbanization

Figure 2.7 The Demographic Transition in Developed and Developing Countries



Source: World Bank, 1984, Reference 18, p. 59.

■ Increase in the marriage age of women

On the other side of the equation are changes that enhance fertility and that often accompany "modernization". These include a reduction in breastfeeding, a departure from traditional customs such as long periods of sexual abstinence following childbearing, and relaxation of the custom forbidding widows to remarry.

The state of fertility around the world was assessed by the World Fertility Survey (WFS), the largest social science survey ever undertaken. The WFS covered 42 developing and 20 developed countries between the years 1974–82. Over 300,000 married women between the ages of 15 and 49 were interviewed, providing internationally comparable data on fertility levels and trends, and women's aspirations concerning the size of their families. Prior to the WFS, good-quality, comparable data were hard to come by. Undoubtedly, the WFS's most important contribution was the demonstration that although economic development and family planning programs can each independently promote fertility decline, the effect is greatest and most rapid when the two occur together.

Table 2.3 Percentage of Population Increase that Has Permanently Emigrated[a]

Period	Europe	Asia[b]	Africa	Latin America[b]
1851–80	11.7	0.4	0.01	0.3
1881–1910	19.5	0.3	0.04	0.9
1911–40	14.4	0.1	0.03	1.8
1940–60	2.7[c]	0.1	0.01	1.0
1960–70	5.2	0.2	0.10	1.9
1970–80	4.0	0.5	0.30	2.5

Notes:

[a] Numbers are calculated from data on gross immigration in Australia, Canada, New Zealand, and the United States.

[b] The periods from 1850 to 1960 pertain to emigration only to the United States.

[c] Emigration only to the United States.

Source: The World Bank, 1984, Reference 18, p. 69.

Unmet Need for Contraception

The WFS found that many women were having more children than they said they wanted. Women in the survey responded to a question that asked how many children they would have "if they could choose exactly." In Latin America, women would have two or three fewer children if they could choose. In Asia and the Pacific, women were also having more children than they wanted; the desired number of children in Bangladesh was 4.1 per woman, while the average woman actually had 7.5. In North Africa, the trend held true. All told, of

Box 2.2 The World's Fastest-Growing Population

Why do Kenyans have so many children? Africa has the fastest-growing population of any continent, and Kenya has the fastest-growing population in Africa. The average Kenyan woman has 8.1 children, although there are tentative signs that people may choose to have fewer children in the future (1,2).

Kenya's population of 20.6 million is growing at the rate of 4.1 percent per year. At that rate it will double in a mere 17 years. According to the United Nations medium projection, by 2025 Kenya will be home to 83 million people. Moreover, Kenya is a young country, with over 50 percent of the people under the age of 15 (3).

"Kenya represents a very crucial country with regard to population policies and programs, as Kenya's experience will likely affect other African countries," says Rafael M. Salas, Executive Director of the United Nations Fund for Population Activities (4).

Kenya's rapidly expanding population occupies a medium-sized country of largely arid or semi-arid land, only 20 percent of which is fertile farmland. Straddling the equator on the east coast of Africa, Kenya encompasses barren steppes, grassy plains, highlands, a lake region and a strip of coastline (5).

Most of the people are concentrated in the fertile 20 percent of the country, where they work the land. As population pressures build, readily exploitable farmland is becoming scarce. Increasing numbers of people try to farm marginal lands and fragile ecosystems that often turn to dusty wastes under the hoe and the plow. Swelling waves of rural migrants head for the cities, which are undergoing tremendous strains from overcrowding. The urban population is growing by 7.36 percent per year.

POPULATION OUTSTRIPS ECONOMY

Kenya's population is outstripping its economy. The Kenyan gross national product grew at a healthy clip of 5 percent per year between 1975–83. But that just exceeded the country's population growth, which is increasing at the rate of 4.1 percent per year.

Calculations by the World Bank show that Kenya spent 32 percent of total government expenditure on education, health, rural water supply and urban housing during the period 1975–80. If current fertility rates continue, the country will need to spend almost nine times as much in the period up to 2015–20 just to maintain current standards. An estimated 11 million new jobs will have to be provided by the year 2000, in addition to those needed to accommodate present underemployment or unemployment (6).

The main reasons for the recent surge of growth are that more babies in Kenya are surviving the precarious first year of existence, and people are living longer lives. Although there have been some indications of increased fertility among younger women, most of the growth results from improved health and living conditions (7,8).

In the last century, people lived shorter lives due to famines, slave raids, and tribal wars. In the early part of this century, sleeping sickness, malaria, plague, and malnutrition contributed to a high mortality rate. Infants are believed to have died at the rate of perhaps five for every ten born.

By the time of the 1948 census, health conditions were considerably improved and for every ten births, about two infants died before the age of two. By 1985, the infant mortality rate had further declined to the rate of less than one death in the first year of life, for every ten births. Additional improvements are expected. For example, family planning enables women to lengthen the interval between births, and this improves the infant's chances of survival (9).

In Kenya, mothers whose babies are most likely to survive their first year are those who live in an urban area, are educated, do not live in polygamous unions, are not too young, and have not had more than five or six children (10).

The average Kenyan born in 1955 lived only 39 years while a Kenyan born today can expect to live 55 years. Though a substantial improvement, this is still a much shorter life than the average of 74 years a person born in the developed world can expect (11).

NOT ONLY ROGUES AND ROBBERS

The question of why Kenyans continue to have so many children has not yet been completely answered, although it is attracting the interest of many researchers. An informal survey of health workers from many parts of the country revealed the following, highly personal replies.

- "Amongst many children there are likely to be not only rogues and robbers but also professionals such as doctors, lawyers, engineers, etc."
- "A wife continues to bear children to prove her continued fecundity to prevent the husband from marrying another wife."
- "Wives in polygamous families compete with each other to produce the largest number of children."
- "Children provide labor for fetching firewood and water and for digging in the fields."
- "Children are an investment as they provide old age security for the parents."
- "Women have no say in determining the size of the family" (12).

In general, most women have little status in Kenyan society unless they have children, preferably many children.

FAMILY PLANNING PROGRAMS

An important question for the future is the extent to which Kenyans will adopt family planning. The government has supported family planning programs for almost a decade. "Although Kenya officially adopted family planning programs in 1966 with a view to reducing the rate of growth of population, this has not succeeded," says President Arap Moi. Recognizing the problem, the government established a National Council for Population and Development in December 1982. The Council has the primary responsibility of introducing information and education programs for the establishment of a small family norm.

The World Fertility Survey showed that Kenyan women with secondary or higher levels of education are likely to have fewer children. And according to the Kenyan Fertility Survey, younger women want fewer children than older women want (13).

These and other factors may signal the start of a transition toward lower fertility, but the trend is still unclear. Indeed, traditional practices that formerly served as a brake on fertility (such as breastfeeding and sexual abstinence for a long period following the birth of a child) are now less prevalent. At this stage, fertility may actually increase (14).

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13. *Op. cit.* 7.
14. *Op. cit.* 7.

the women surveyed in 31 countries, about half did not want any more children. (See Figure 2.8.) However, in sub-Saharan Africa, women seemed to want as many children as they could have.

Thus, the WFS revealed a substantial, though widely varying, unmet need for modern contraception (33). The figure for rural Mexico was 58 percent of women aged 14–49, while in Asia it varied between 9 percent in the Yemen Arab Republic and 53 percent in Fiji. In Bangladesh, the Republic of Korea, Malaysia, and Thailand, it was about 30 percent. The figure for Ecuador, urban Mexico, Colombia, and Paraguay also stood at 30 percent. The lowest figures for unmet contraceptive need were found in Africa, from 5 percent in Benin to 21 percent in Egypt.

Education and Fertility

The survey also showed that women in higher educational groups generally had fewer children than their counterparts with little or no education (34,35,36,37). Analysis of WFS data for 30 countries (38) showed, however, that a few years (one to three) of education seem to be associated with higher recent fertility rates, possibly due in some cases to the disruption of traditional contraceptive practices.

Many, but not all, countries show a direct and consistent relationship between increasing levels of education and decreasing fertility; these include Senegal, Tunisia, Costa Rica, the Dominican Republic, Jamaica, Panama, Peru, Venezuela, Jordan, Malaysia, Nepal, the Philippines, and the Republic of Korea.

In a few countries, there was a rise in fertility when higher levels of education were reached (nine or more years of schooling). This trend appeared in Ghana, Colombia, Paraguay, Bangladesh, Pakistan, Sri Lanka, and Sudan. This effect may be a result of higher levels of income, rather than higher education (39).

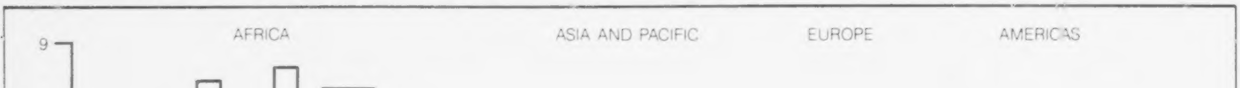
Although the patterns differ among countries, the results clearly demonstrate the importance of education in prompting lower fertility rates. In addition, the WFS showed that in general, the more education a woman had, the more likely she was to use an efficient rather than an unreliable method of contraception (40).

Use of Contraceptives

Current contraceptive use shows striking regional variations among the 27 developing countries studied, with the highest use rates found in countries of Latin America and the Caribbean, followed by Asia and the Pacific. Use of effective means of contraception was especially low in Africa (other than North Africa), ranging from 1.0 to 4.5 percent of women in the study (41).

In China, Hong Kong, and Singapore, an estimated 71–72 percent of married women practiced some form of contraception at the time of the WFS. More than half the married women in Costa Rica, Panama, Puerto Rico,

Figure 2.8 Number of Children Desired in Selected Countries



Source: World Fertility Survey, *Fertility in the Developing World* (International Statistical Institute, London, December 1984)

Jamaica, and Trinidad and Tobago were contraceptive users, as well as about half the married women in Lebanon, the Republic of Korea, Sri Lanka, and Thailand, and a quarter of the women in Egypt and Tunisia (42).

On the low end of the scale, the WFS found that only 5 percent of married women in Pakistan, 7 percent in Nepal, 8 percent in Kenya, and 13 percent in Bangladesh were using any means of contraception.

The largest recent increases in contraceptive use have occurred in Latin America and Asia. India and China were not included in the WFS, but it is known that use has increased substantially in China, and moderately in India.

In most of the 11 developed countries surveyed, contraception was used by about two thirds to four fifths of the married women. For example, the rate of use in the United States was 68 percent; in Japan, 61 percent; in Poland, 75 percent; and in France, 79 percent (43).

No method of fertility regulation is perfect for all individuals or cultures, but the variety of methods available has increased dramatically since the 1950s (44). Prior to 1900, few methods were widely available apart from the traditional ones of withdrawal, douching, delayed marriage, breastfeeding, and abstinence. A relatively unreliable version of the condom became available in the 19th Century. In the 1920s diaphragms with spermicides became available. The intrauterine device (IUD) was proposed in the early 1900s, but was not given serious consideration as an effective method until 1962. Initial human studies were conducted in 1957 for the use of oral contraceptives. Implants, injectables, and the vaginal ring are relatively recent developments.

In most developing countries, relatively effective methods of contraception are now predominant, while in a minority of countries less effective means are more commonly used. In Eastern and Southern Europe, traditional means—particularly rhythm and withdrawal (backed up by abortion in Eastern Europe)—account for about half of contraceptive practice, and in France, for about 40 percent. In other parts of Europe and in North America, more modern methods are chosen by the majority of users.

Son Preference

Among the questions asked in 27 of the WFS countries was one concerning the preferred sex of the next child: "Would you prefer your next (or first) child to be a boy or a girl?" Pregnant women were asked the question, as were those in the survey who wanted at least one more child (45).

In the majority of countries surveyed, there was little or no gender preference. But in six countries, called the extreme son-preference group, about five women wanted a son for every woman who wanted a daughter. In general, women in the Caribbean, Central America, and Africa had no stated preference for sons or daughters, while women in Asia and the Arab countries of the Middle East exhibited strong or moderate son preferences.

To what extent does gender preference influence the number of children people have? Son preference appears to elicit a positive fertility response (people have more children than they would otherwise have) in Korea, Malaysia, Nepal, Pakistan, Fiji, Mexico, Paraguay, and Trinidad and Tobago. Where marital fertility is largely uncontrolled, an effect should not be possible no matter how strong the preference. In countries such as Pakistan and Nepal, analysts hypothesize that unrecorded birth control, or reduced coital frequency, may be responsible. In Jamaica and Haiti, daughter preference may influence fertility (46).

In countries where families are usually large, as in many African countries, the parents are liable to have both sexes represented among their offspring, and gender preference may not play a major role.

India and China were not included in the World Fertility Survey, but it is known that a strong son preference exists in both countries. The results of the WFS thus reinforce the concept that son preference is a widespread—though by no means universal—attitude that in some cases influences fertility behavior.

Patriarchy and Fertility

The WFS gender preference data have been analyzed in relation to patriarchal family structure using the age difference between husband and wife as the measure (47). Patriarchal societies are generally characterized by a large age difference between spouses, the supremacy of the father in the clan or family, the legal dependence of children and wives, and the reckoning of descent and inheritance through the male line. By relating the median age differential between spouses to total fertility rates, the study showed a positive relationship between high fertility and a strong patriarchal structure. Fertility reduction in such societies appears to be much more difficult than in non-patriarchal societies.

Patriarchal structures have developed over thousands of years, (48,49,50) and although weakened considerably in many parts of the developed world, they continue to exert powerful influences over the lives of many women in the Third World. (See Box 2.3.) More research needs to be done to establish the mechanisms by which patriarchal societies regulate fertility decisions (51,52,53).

Male Attitudes

Nearly all family planning programs are still formulated for women, but men are beginning to receive increased attention. However, the extent to which male views determine fertility decisions, and men's views concerning the number of children they would like to have, are still largely unknown.

A recent study of men aged 18–54 in Santiago, Chile, found that most men in that urban area and a neighboring village felt that men and women shared equally in fertility decisions (54). This contrasted with an earlier study of white-collar males of Sao Paulo, Brazil, where 86 percent of the husbands felt the man was mainly responsible for determining the number of children (55).

Although many observers have suggested that male dominance in Africa is partially responsible for high fertility rates, empirical data are scarce (56). There are,

Box 2.3 A Way Out For Women In Bangladesh?

Where women have "no exit" from poverty and live under a strong patriarchal system, changes that would allow them more control over their own lives are not easily introduced or accepted. Bangladesh is an example of such a society. Yet the government of Bangladesh seems to have found a way. In 1974 a program was introduced to simultaneously provide an opportunity for rural women to engage in income-generating activities and to provide them with access to information on family planning, health, nutrition, and literacy training (1).

In rural Bangladesh, male dominance is established through control of material resources and through a series of reinforcing elements throughout the society. Men hold almost all the positions of power; they dominate the political and legal institutions, and legal protection of women is nominal. The religion of Islam calls for the sexual division of labor and in effect may be interpreted as sanctifying male dominance.

When a Bangladeshi woman marries, she moves to where her husband lives, and has reduced contact with her own family. Arranged marriages and age differences between husband and wife of about ten years, on the average, place her in a subordinate position.

Women in Bangladesh are generally subjected to *Purdah*, whereby they are restricted to their home compounds, and are required to wear clothing that conceals both form and face. Thus it is not easy for them to work outside the home, and they are denied income-earning opportunities. However, they put in long hours of household work.

Women are heavily dependent on their husbands for support, and if the husband should die before the wife (as is usual, because of age differences between spouses), the woman becomes dependent on her son. Thus there is a strong incentive for a woman to produce sons, not only to please her husband and family, but to secure her own social and economic future. Without sons to rely on, widowhood, divorce, or abandonment can leave a woman destitute.

Parents consider sons necessary to inherit and maintain control of land (2). Under Muslim law a daughter can receive only one half the share of an inheritance received by a son. Without a male guardian, women run the risk of losing any land they do inherit.

About 90 percent of the people in Bangladesh work in agriculture, and about 80 percent of the cultivable land is in production (3). Children start working early, helping with household and agricultural tasks; 60 percent of the boys and 90 percent of the girls start working by the age of ten, and by the age of 12 nearly all of them join the family labor force. Compulsory primary education would no doubt change this pattern (4).

A government report published in 1981 indicated that 11 percent of married women in Bangladesh were using some method of contraception at the time of the study (5). An official family planning program has been in operation since 1962 (6).

The total fertility rate, though falling, is still high—6.15 during 1980–83—and the country's population growth rate for that period was 2.74. In 1985, the estimated population was 101 million. By the year 2020 it may have more than doubled to 206 million, according to U.N. estimates (7).

WOMEN'S COOPERATIVE PROJECT

In 1974, the Women's Cooperative Project, a part of the government's Integrated Rural Development Program, started establishing cooperative associations for rural village women. Membership in a cooperative costs about ten cents, and women are required to deposit their savings weekly, attend weekly village cooperative meetings, and send representatives to a training and development center every week. There they are provided with modern training, supplies, services, and improved family planning and health programs. Topics may include poultry raising, horticulture, hygiene measures, or loan policy. Once the village leaders have endorsed a local cooperative, the members are entitled to credit for individual and group economic enterprises (8).

The cooperative decides who should receive loans as well as the size of the loans. Women have taken loans for the processing of mustard oil, chili, turmeric, fish, and peanuts; the purchase of livestock and poultry to raise and sell; the financing of small enterprises such as pottery-making; or to buy water or lease land for cultivation (9). So far, demand has far outstripped resources. Repayment rates have been very high, approaching 100 percent.

From 1974–84, the women's cooperatives expanded to cover 100 of the 473 *thanas* (or administrative units) in Bangladesh. As of December 1984, the government program was assisting 1,700 cooperatives with 67,000 members. Estimated project costs for the period 1980–85 are between $2 million and $2.5 million.

The project had a population goal as well as an economic one. As described by its first director, the project was "based on the clear assumption that rural women are responsible people whose contraceptive behavior is part of their total response to their culture. The major effort of this project, therefore, has to be to explore ways to bring about changes in their culture, so that contraception could be an acceptable choice," and to make that choice available to them (10).

The Integrated Rural Development Program was seeking to slowly bring about fundamental changes in the lives of rural women, in which the decision whether to practice contraception is part of a complex fabric involving economic insecurity, social exposure, family prestige, and other factors (11).

Again, in the words of the project's founders, "the presence of 50 village women of varying ages, both unmarried and married, in a classroom to learn about contraception and discuss their problems, represents a great change in rural areas and offers an important opportunity for the government to reach a large number of rural women and to improve its services to them" (12).

A July 1983 study indicated that 66 percent of all eligible cooperative members had accepted family planning. Those classified as "eligible" included all women aged 15–44, married, with husband present, who had not given birth in the last six months. This compares with an acceptance level of 34 percent at a family-planning health services project that did not have an economic development component (13,14).

Although the 66 percent acceptence rate for the Women's Cooperative Project is an impressive accomplishment, the project goal is a further 25 percent increase in the number of women using contraception. Plans for the next five years call for an expansion of the program to double the number of women covered, and double the members' average income to $93.

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however, some examples that contradict the stereotype that men want many children to prove their masculinity, are negatively disposed to family planning and unwilling to use birth control, and have little concern for the well-being of their partners (57).

A project sponsored by the government of Ghana in the early 1970s organized mobile family planning teams in the Danfa region north of Accra, the capital city. Traveling from village to village to provide birth control services, these units were supplemented by maternal and child health care centers and by primary care health workers in the area.

Although originally intended as a program for women, it soon became apparent that half the clients were men. The men in the male-dominated Danfa society became more conscientious users than the women, and were persuasive advocates of contraception. Fertility was reduced in the Danfa area, and it was estimated that about half of the reduction was accounted for by the men's acceptance of contraception.

Employment and Fertility

World Fertility Survey data for 30 countries show that women working away from home in the urban or modern market economy, and those in higher-status occupations, had fewer children than other women in their respective countries. Women in low-paying, low-status jobs were likely to have fertility rates as high as or higher than women who had never worked. Women working in agricultural jobs also had higher fertility levels (58).

In most of the developing countries surveyed, fertility was higher for women who had not worked since marriage than for women who had worked at home or away from home. Contrary to expectations, in almost half of the countries, women working away from home had higher fertility than did those who worked at home.

However, the relationship between fertility and work is a very complex one, for a variety of reasons. First, the concept of "work" differs considerably among countries. Fertility, family size, age, and other factors affect the likelihood of participation in the labor force, and *vice versa*. And finally, the distinction between "not working" and "working at home" was often blurred, perhaps due to differing cultural definitions of "work." The WFS generally considered work in addition to the usual housework, but even this distinction was not clear, for in some countries it included work on the family farm and in others it did not (59). In industrialized countries there is a stronger and more consistent relationship between women's work and fertility, with working women having fewer children (60).

Urban-Rural Differentials

City life is evidently conducive to smaller families, according to analysis of World Fertility Survey data from 29 developing countries. Women in the study were categorized as residing in one of three types of areas: major urban areas (cities with a population exceeding one million, and capital cities), other urban areas, and rural areas. The distinction between "other urban areas" and "rural areas" is unclear, as countries use different definitions. (See Chapter 3, "Human Settlements.")

Nevertheless, the study showed that fertility rates in rural areas were higher than in urban areas in nearly all countries (61,62). In a few countries in Africa and Asia, little difference emerged between rural and urban areas. The results were adjusted to take account of such factors as the women's age, education, age at marriage, work status, and occupation of husband. In some countries, as in Kenya and Venezuela, rural women bore 40 to 50 percent more children than urban women. The only country where urban women were more fertile was Pakistan, where they produced 15 percent more children than their rural counterparts.

Summary

Fertility is an extremely complex behavior, influenced by dozens of factors. Recent research shows clearly that in addition to access to effective means of contraception, cultural and socioeconomic change are important. In particular, new opportunities for women—through education and a higher status within the family and outside the home—play unmistakable roles in lowering fertility.

MIGRATION

Over the past half century, the character of international migration has changed. Where in the past the international migrant stream was primarily made up of Europeans who settled in the New World, most migrants now come from Asia and Latin America (63,64).

Today, although the United States has taken increasing numbers of immigrants, there are fewer permanent places available for migrants in the three other traditional immigration countries: Canada, Australia, and New Zealand. Other target areas have opened up for foreign workers, particularly in the oil-rich countries of the Middle East.

Labor migration to Western Europe was strong up to the early 1970s (65,66). During just one decade, more than 30 million foreign workers, primarily from Mediterranean countries, migrated to Western European countries, after a European Economic Community (EEC) regulation granted member states the right to recruit migrant workers from countries outside the EEC. In 1973, one seventh of the Western European labor force consisted of foreign workers.

The economic recession that followed the oil crisis of 1973–74 disrupted migration patterns, and many of the migrant workers returned home. The European host countries tightened their policies with regard to admission of migrant workers, but continued to accept permanent immigrants and refugees (67). One consequence was illegal migration. Pressed by population growth and unemployment in their home countries, many migrants sought and found illegal means of reaching their goals. Overall, however, the flow of migrants to Western Europe since 1974 has remained relatively small (68).

In Africa, large flows of refugees have constituted the major form of migration. Few African governments have accepted permanent migrants on any large scale, though some Arab countries allow substantial numbers of foreign workers (69). In Asia, there is currently very little immigration for permanent settlement but there has been large-scale labor migration to West Asia. In Latin America there is substantial intra-regional migration, much of it unauthorized. Venezuela is Latin America's major receiving country.

POPULATION POLICIES AND PROGRAMS

When India included family planning in its First Five-Year Plan for 1951–56, it became the first government in the world to adopt a national family planning program. Since then, the perceptions of developing country governments have undergone an unprecedented change. Many governments that previously considered it unnecessary or even harmful to introduce population policies have reversed their positions as the impacts of population growth on socio-economic development have become apparent. By 1984, 80 of the 126 developing countries had official family planning programs, according to one estimate. In addition, 14 other countries indirectly supported family planning information through private or semi-governmental agencies (70).

Most developing country governments finance about half the cost of family planning programs in their countries, with external assistance providing the balance. In China, the government finances nearly all the cost of its program, and India finances 80 percent of its program. (These two countries together account for nearly 40 percent of the world's population.)

In 1980, China spent about $1 and India spent about 30 cents per capita on population programs. Other developing countries for which data are available spent within this range. If other developing countries were spending equivalent amounts, the total for the Third World at that time was about $2 billion. Overall, the amounts spent, in relation to other government outlays are tiny: less than 1 percent (71).

Population programs also account for only about 1 per cent of external assistance funds, a mere $500 million. During the 1970s, external assistance increased by about 6 percent a year, but it fell by 3 percent in 1980 and by 6 percent in 1981 (72). The United Nations Fund for Population Activities (UNFPA), a major source of external assistance, is troubled by uncertainties regarding contributions by the United States, traditionally UNFPA's largest donor. (See "Recent Developments," below.)

Private suppliers provided about a quarter of family planning services; in some countries or regions—such as Korea, and Latin America—they play a more dominant role.

Taking into account all public spending on family planning in developing countries—including spending for contraceptive services; program administration; information, education, and communications activities; research and evaluation; and personnel training—the per capita cost averages about 70 cents a year. However, only a small percentage of Third World people—most of them in India and China—use contraceptives, so the average cost per user is higher: about $11. If private expenditures in all developing contries were added, the cost per user would probably be double that amount (73).

The costs of meeting the unmet need for contraception have been estimated by the World Bank at roughly $1 billion in additional annual public spending (74).

However, the number of women of childbearing age is increasing (from 500 million in 1980 to 700 million in 2000) and a growing fraction is expected to want to use modern contraceptives. If a "rapid" fertility decline to a total fertility rate of 2.4 were to be reached by the year 2000, the World Bank estimates that 72 percent of married women of reproductive age in developing countries would have to be contraceptive users, up from 40 percent today. The sum required for such a decline, assuming the 1980 cost per user, would be $7.6 billion in annual public spending by the year 2000, an increase in real terms of 7 percent a year (75).

RECENT DEVELOPMENTS

THE INTERNATIONAL CONFERENCE ON POPULATION

One of the indicators of the increased commitment to population programs was the remarkable international consensus that characterized the August 1984 International Conference on Population, held in Mexico City. In contrast to the first World Population Conference, held in Bucharest in 1974 at the urging of the developed nations, the Mexico City meeting was convened at the request of the developing countries, several of whom vied for the privilege of hosting it. Whereas at Bucharest—a meeting marked by major confrontations between developed and developing countries—key developing countries argued that "development is the best contraceptive," at Mexico City virtually no one questioned the principle that population policies and programs are integral elements of economic development.

The policy position adopted by the U.S. delegation barely fit within this consensus, even after much compromising between U.S. conservatives opposed to population control programs and elements within the U.S. Government traditionally supportive of Third World family planning programs. While arguing that interference with free markets—not population growth—was the source of economic problems in the Third World, the U.S. policy statement did agree that rapid population growth compounds already serious economic and social problems. It affirmed U.S. support for voluntary family planning programs in the Third World as an ingredient in a comprehensive effort to address root causes of poverty, but announced that the United States would not support coercive population control programs nor provide assistance to multilateral or nongovernmental organizations that perform or promote abortion.

However, the U.S. position appeared to have made little impact on the set of 88 recommendations adopted by the representatives of the 146 governments participating in the conference. It is even possible that the controversial U.S. position made it easier for many nonaligned countries to subscribe openly to the principles and approaches laid out in a strengthened "World Population Plan of Action." The same dynamic may have been at work in July 1985 at the International Women's Conference in Nairobi where Third World women aggresively challenged western anti-abortion and natural family planning activists and reconfirmed the major recommendations of Mexico City on family planning and the status of women. (See Chapter 4, "Food and Agriculture," Recent Developments.)

The recommendations of the Mexico City conference affirmed that governments have a responsibility to make universally available the information and means for couples and individuals to make decisions about the number and spacing of their children. The conference also deplored coercion, and agreed that abortion should not be promoted as a method of family planning.

A full section was included in the recommendations on measures needed to protect and enhance the status of women, and special attention was urged for maternal and child health care. Other recommendations covered integrated development strategies, the importance of nongovernmental organizations, the rights of migrants, and programs for the elderly and youth. As summarized in the Declaration of Mexico, the deliberations of the 1984 Population Conference were a high-water mark in the 30-year struggle for worldwide population awareness (76).

POLICY SHIFTS IN THE UNITED STATES AND ELSEWHERE

Within the United States there has been a perceptible slackening of traditional support for international population programs. Although the U.S. Congress steadily increased funding for U.S. population assistance from $190 million in 1981 to $290 million in 1985, budget levels for 1986 and 1987 are likely to decline.

In December 1984, the U.S. Agency for International Development (U.S. AID), in keeping with new U.S. anti-abortion policies announced at Mexico City, ended its 18 years of support for the International Planned Parenthood Federation (IPPF). The $17 million in U.S. cash contributions and contraceptive commodities represented one quarter of IPPF's budget. Plans for new national family planning programs, including 13 new affiliates in Africa, were canceled.

Early in 1985, U.S. contributions to the United Nations Fund for Population Activities also came under attack because of UNFPA support for programs in the People's Republic of China. The U.N. Fund for Population Activities is the largest source of multilateral assistance to population programs and operates in over 100 countries. The U.S. Agency for International Development withheld $10 million from a $46-million contribution pledged to UNFPA and earmarked by Congress. In 1985, Congress prohibited U.S. support for any organization that "participates in the management of a program of coercive abortion or involuntary sterilization." Future U.S. contributions to UNFPA are in jeopardy, as are contributions to other organizations with programs in China and in some half-dozen other countries where accusations of coercion have been made.

Other policy shifts are gradually changing the profile of United States population assistance abroad. As longtime grant agreements with major nongovernmental family planning organizations come up for renewal, U.S. AID is insisting on new contract language. Some organizations have signaled that they cannot comply and will fall out of the program. Such private groups now work in some 70 countries, compared to direct U.S. government-to-government programs in only 30 countries. Private sector programs are also generally more innovative and cost-effective. Since 1981 U.S. AID has also increased 20-fold (from $400,000 to $8 million) its support for natural family planning—methods that rely on sexual abstinence for up to half the menstrual cycle. These programs have been exempted from U.S. AID's longstanding requirement that family planning services describe all available contraceptive choices.

Outside the United States the general trend has been a strengthening of government commitment to population and family planning programs. Other donor nations such as Germany and Japan have steadily increased their external assistance for population, despite level funding for other sectors in some cases. In 1985, a few western donors consciously sought to make up part of the shortfall resulting from U.S. cuts to IPPF and UNFPA. Among the developing countries, Indonesia, Thailand, India, Pakistan, Bangladesh, Egypt, Sudan, Kenya, Nigeria, Mexico, Brazil, and at least a dozen others, are moving to expand and strengthen family planning services.

But there are also signs that population programs may soon be in political trouble in a number of countries, for some of the same reasons that have caused debate in the United States: the resurgence of religious fundamentalism; public concerns over abortion, sexual promiscuity, and threats to the family; questions about contraceptive safety; and a backlash against population control programs perceived to violate individual rights.

The examples are mounting. In 1985 Sweden withdrew from the World Bank donor consortium for Bangladesh's population program, citing objections to incentive payments for sterilization and insufficient attention to primary health care. Conservatives in Great Britain and Canada have threatened to withdraw support by those countries for the International Planned Parenthood Federation over the abortion issue and services for adolescents.

In a number of developing countries indigenous anti-family planning movements are also on the rise, sometimes aided by organizations based in western countries. In Mexico, Guatemala, Peru, El Salvador, and the Philippines, conservative Catholic groups have challenged national family planning programs with mixed results. In Egypt, Iran, Sudan, and Pakistan, Moslem fundamentalists have moved against both family planning and recent measures to improve the status of women. Opponents of family planning argue that western donors are dumping dangerous contraceptives on unsuspecting Third World women and promoting population control in order to contain the growth and power of non-white populations.

RECENT TRENDS IN INFANT MORTALITY

The 1980s have been harsh years for vulnerable populations, and especially hard on infants and children, whose survival often depends on the availability of medical care for mother and child in the critical months before and after birth. In a broader sense, it also depends on economic conditions that affect pregnant and nursing women's nutritional status, the availability of adequate housing and water supplies, and the stability of household incomes. On all counts, conditions have deteriorated in many parts of the world.

Throughout most of sub-Saharan Africa, per capita food supplies and household incomes have fallen. In most of Latin America, the debt crisis has forced severe economic retrenchment that has reduced per capita incomes and government spending for public health and welfare. Even in industrial countries such as the United States and the Soviet Union, economic conditions and shifts in government programs have affected infants' chances for survival (77).

Thus, throughout much of the world, the slowdown in the pace of infant and child mortality improvements that was already evident in the 1970s has apparently continued into the 1980s. From the 1960s to the 1970s, the gains in infant mortality decelerated somewhat by comparison with the previous decade. The change was centered in Latin America, but was also evident in Africa (78). Events in China, as well as in the rest of Asia, ran markedly counter to this trend. Subsequent analysis has suggested that only part of the observed slowdown can be explained by the slower pace of developing countries' economic growth in the later period. The rest must be attributed to a marked decline in mortality improvements unrelated to improvements in income, literacy, and food supply (79). Throughout the earlier postwar period, these gains, due mainly to better medical services and technologies, had been responsible for as much as half of the overall improvement in infant and child mortality. However, in the 1970s this trend decelerated by as much as two thirds.

Although there are not yet sufficient data to assess the situation in the 1980s comprehensively, recent estimates of infant mortality in countries where vital registration data are reasonably reliable suggest that the slowdown has continued. In Costa Rica, for example, where the infant mortality rate fell from 34 per thousand in 1970–75 to 20 per thousand in 1980, it remained at 18.6 per thousand in 1983. In Argentina, where the infant mortality rate had fallen from 58 per thousand in 1970–71 to 33 per thousand in 1980, it dropped to 28 per thousand by 1983. In Barbados, the decline was from 34 to 23 deaths per thousand in the 1970s, but no further fall was recorded by 1983. In Cuba, the rate fell from 36 to 20 in the 1970s, and by 1983 it reached 16.8, a somewhat slower rate of decline. In Panama, the fall during the 1970s was from 52 to 22, and in 1983 the recorded rate was 20.4. In Chile, however, a similar comparison shows the decline from 82 to 32 in the 1970s and a fall to 22 by 1983, which maintains the rapid improvement (80). Overall, the indicators available suggest that mortality gains have slowed so far in this decade.

These indications are reinforced by recent trends in the United States, where the rate of fall in infant mortality declined from 4.6 percent per year in the late 1970s to 2.6 percent in 1983 and 1984 (81). The reasons are complex. The sharpest declines in U.S. infant mortality occurred in the 1970s, when programs to improve family welfare (including Aid to Families with Dependent Children, food stamps, and Medicaid), health, family planning, and abortion services were all more widely extended. Advances in medical techniques of caring for premature and abnormal infants also took place, as did important economic gains for households near the poverty line.

Among the explanations advanced for the slowdown in infant mortality gains are the increasing numbers of teenage and out-of-wedlock births; the cutbacks in family planning, abortion, and welfare programs; an increase in the number of households below the poverty line; and increases in the percentages of younger women who use tobacco and alcohol.

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3. Human Settlements

For more than 200 years, the world's population has tended to concentrate in a relatively small part of the earth's surface—in towns and cities. But the pace of this process—called urbanization(1)—has accelerated sharply during the 20th Century. In 1985, urban dwellers comprised an estimated 41.6 percent of the world population, compared with 33.6 percent in 1960 and 13.6 percent in 1900. During the past 25 years, virtually all countries have experienced an increase in the proportion of the population living in urban centers.

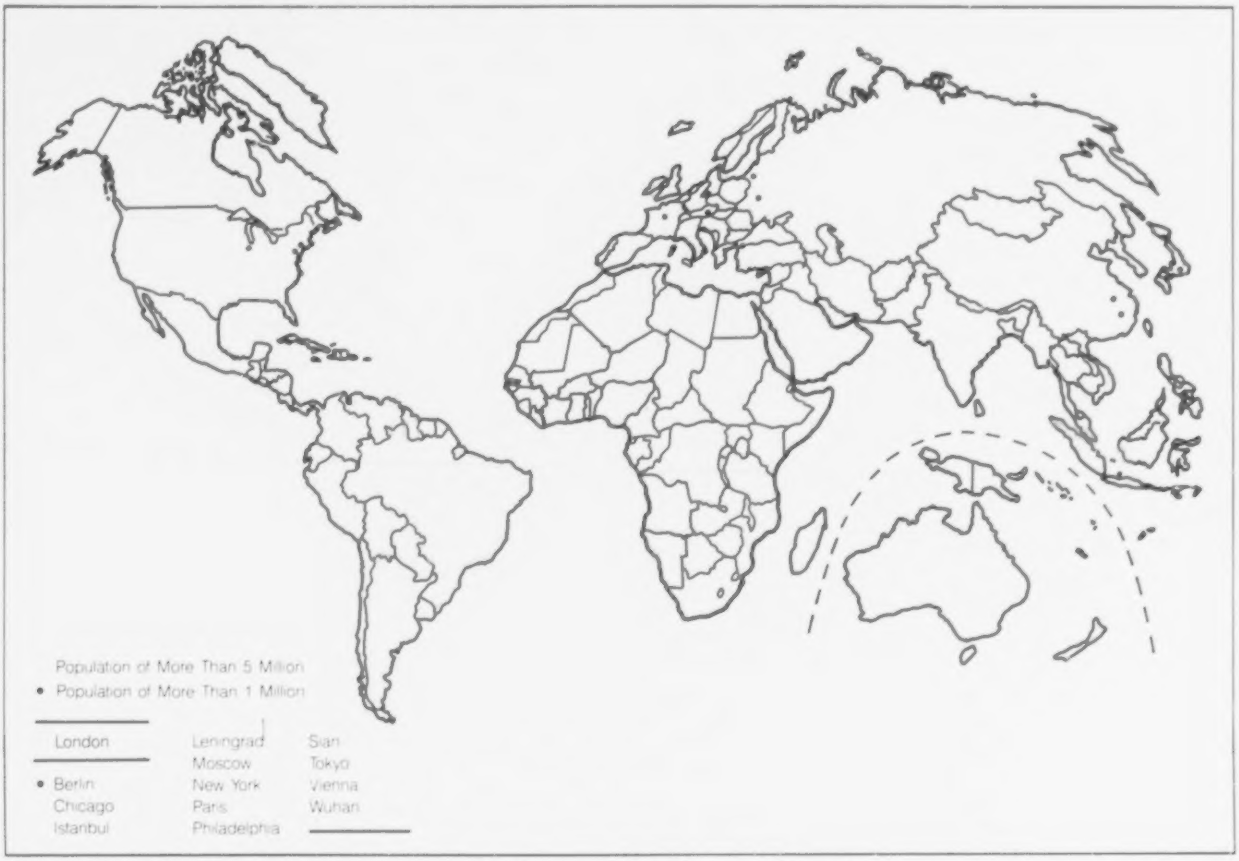
Another gauge of the extent to which urbanization is increasing is the number of major cities. In 1980, there were about 230 cities with a population of 1 million or more, compared with only 13 in 1900. (See Figures 3.1A and 3.1B.) In most Third World countries, the urbanization of the past few decades has been concentrated in a few key metropolitan areas or "core regions." These not only contain a significant proportion of a nation's population, but also dominate the national economy, often to the detriment of residents of outlying areas. The mushrooming populations of the major urban centers can overwhelm a developing country's ability to provide housing, sanitation, and other important services. A common side effect of increasingly crowded conditions is severe pollution.

While urbanization has been the most significant feature of trends in the distribution of the world's population during the last century or so, a global view of this phenomenon can obscure the tremendous diversity in patterns of human settlement and the complicated mix of local, regional, national, and international factors that underlie these patterns. (See Figures 3.2A, 3.2B, and 3.2C.) Changes in the countries of the Third World, for example, are often markedly different from those taking place in First World or Second World nations. (See Table 3.1.) And even within the Third World, the type and degree of changes can vary greatly among nations, as well as among the cities and regions of a single nation.

Research on human settlements is often further complicated by the lack of data needed to assess changes in population distribution. Comparisons are also handicapped by data inconsistencies. For example, each nation has its own criteria for an "urban center," and differences in the criteria limit the validity of most international comparisons of levels of urbanization or growth rates of urban populations. (See Box 3.1.) Furthermore, definitions of metropolitan areas vary considerably, as do definitions of the central city in a metropolitan area (2).

This chapter focuses primarily on urbanization and only briefly discusses trends and conditions in rural areas, where the majority of the world population still lives. Human settlements for the world's rural population will be analyzed in depth in *World Resources 1987*. But because the urban system can be so extensive that it

Figure 3.1A Major Cities of the World, 1900



Source: V. Showers, *World Facts and Figures* (John Wiley and Sons, Chichester, New York, Brisbane and Toronto, 1981).

greatly influences conditions in rural areas, addressing rural and urban trends as completely independent of each other is inappropriate.

RURAL-URBAN INTERDEPENDENCE

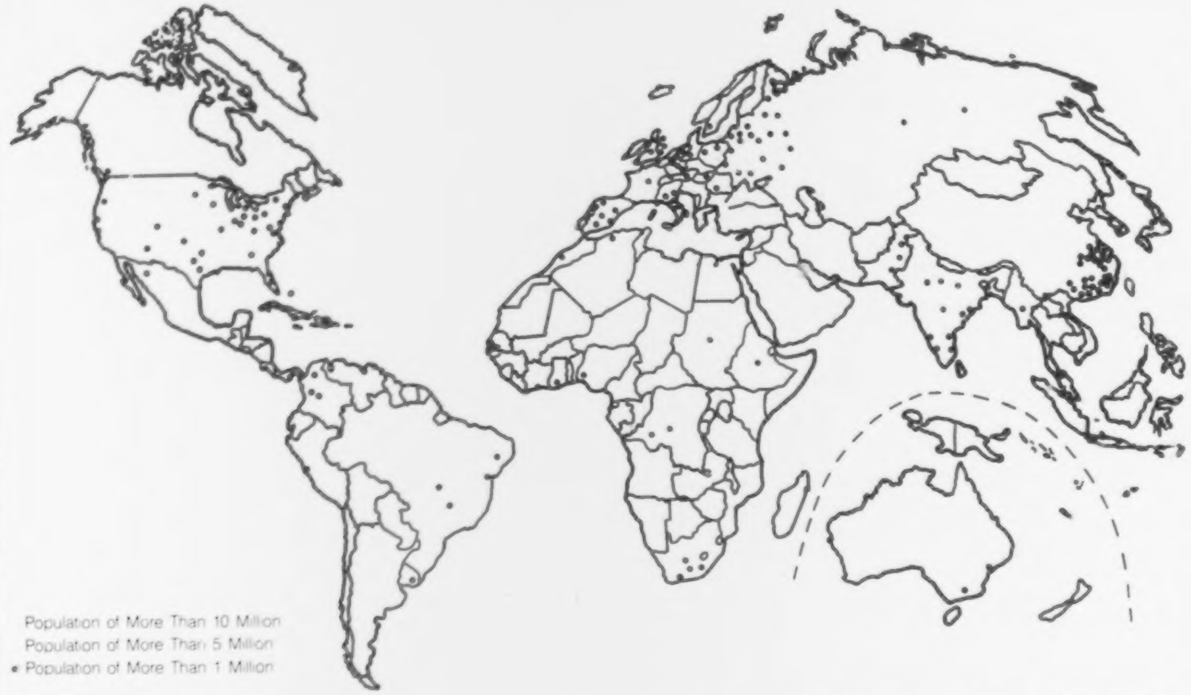
About three out of five people in the world live in rural areas, the vast majority in Third World nations, particularly those in Africa and Asia. In Africa, the rural population accounted for about 70 percent of the total population in 1980; in Asian Third World nations the rural population comprised about 75 percent of the total. (See Table 3.1.) The countries of Latin America tend to be relatively urbanized, more closely resembling the nations of the First and Second Worlds.

While urban centers continue to attract larger and larger portions of the population in most nations, the process of urbanization has ceased in some First World countries. In some regions of the United States, urbanization has given way to "ruralization" (3). Between 1970 and 1980, the rural and urban populations of the United States grew at equal rates, but in the industrialized Northeast the percentage of people living in urban areas and the total urban population actually declined. An analysis of the reversal of urbanization in the United States suggests that one of the major factors fueling rural population growth is the creation of new jobs, which are being added as rapidly in rural areas as they are in urban areas. This population growth in outlying regions has resulted in areas being reclassified from rural to urban (4).

Despite rapid urbanization in many Third World nations, the rural population of the Third World has grown substantially—from 1.5 billion in 1920 to 2.5 billion in 1980—and it is projected to reach 3 billion by the year 2000 (5). A significant proportion of this rural population lives in poverty. According to an analysis of 68 developing countries by the Food and Agriculture Organization (FAO), the incomes of about half the 1.34 billion people living in the rural areas of these countries fell below the poverty line in 1980 (6). Nearly two thirds of the rural poor were concentrated in the Far East.

The FAO estimates that nearly 60 percent of the people in the Third World make their living from farming (7), compared, for example, with less than 5 percent in the United States. Of the 1.3 billion people involved in agricultural production in developing countries (excluding China), about seven of every ten either farm small

Figure 3.1B Major Cities of the World, 1980


Population of More Than 10 Million
Population of More Than 5 Million
• Population of More Than 1 Million

Beijing
Buenos Aires
Cairo
Los Angeles
Mexico City
New York
São Paulo
Shanghai
Tokyo-Yokohama

Bombay
Calcutta
Chicago
Istanbul
Jakarta
Lagos
London
Manila
Milan
Moscow
New Delhi
Osaka-Kobe
Paris
Rhein-Ruhr
Rio de Janeiro
Seoul
Tientsin

- Abidjan
Accra
Addis Ababa
Ahmedabad
Alexandria
Algiers
Alma-Ata
Amman
Ankara
Anshan
Athens
Atlanta
Baghdad
Baku
Baltimore
Bandung
Bangalore
Bangkok
Barcelona
Barranquilla
Beirut
Belo Hoizonte
Berlin
Bilbao
Birmingham
Bogota
Boston
Brasilia
Brussels
Bucharest
Budapest
Buffalo
Cali
Cape Town
Caracas
Casablanca
Changchun
Changsha
Chelyabinsk
Chengchow
Chengtu
Chinchow
Chittagong
Chungking
Cincinnati
Cleveland
Coimbatore
Columbus
Copenhagen
Curitiba
Dacca
Dakar
Dallas
Damascus
Danang
Dayton
Denver
Detroit
Dnepropetrovsk
Donetsk
Durban
East Rand
Florence
Fort Lauderdale
Furtaleza
Frankfurt
Fushun
Genoa
Glasgow
Gorky
Guadalajara
Guatemala City
Guayaquil
Hamburg
Hangchou
Hanoi
Harbin
Havana
Ho Chi Minh City
Hofei
Hong Kong
Houston
Hyderabad
Ibadan
Indianapolis
Izmir
Johannesburg
Kalgan
Kananga
Kano
Kanpur
Kansas City
Kaoshiung
Karachi
Katowice
Kazan
Kharkov
Khartoum
Kiev
Kinshasa
Kitakyushu
Kuala Lumpur
Kucknow
Kuibyshev
Kunming
Kwangchow
Kyoto
Lahore
Lanchow
Leeds-Bradford
Leningrad
Lille
Lima
Lisbon
Liverpool
Loyang
Lucknow
Luta
Lyallpur
Lyon
Madras
Madrid
Madurai
Manchester
Marseilles
Medellin
Melbourne
Miami
Milwaukee
Minneapolis
Minsk
Monterrey
Montevideo
Montreal
Munich
Nagoya
Nagpur
Nanking
Nanning
Naples
New Orleans
Newcastle upon Tyne
Novosibirsk
Odessa
Omsk
Oxnard-Ventura
Paotow
Perm
Philadelphia
Phoenix
Pittsburgh
Poona
Portland
Porto Alegre
Prague
Providence
Pusan
Pyongyang
Rangoon
Recife
Riyadh
Rome
Rotterdam
Salvador
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San Diego
San Francisco
San Jose
San Juan
Santiago
Santo Domingo
Sapporo
Seattle-Everett
Seville
Shenyang
Shihkiachwang
Sian
Singapore
Sofia
St. Louis
Stockholm
Stuttgart
Surabaja
Sverdlovsk
Sydney
Taegu
Taipei
Taiyuan
Tangshan
Tashkent
Tbilisi
Tehran
Tel-Aviv
Toronto
Tsinan
Tsingtao
Tunis
Turin
Ulhasnagar
Valencia
Vancouver
Vienna
Volgograd
Warsaw
Washington, DC
West Berlin
Wuhan
Yerevan

Source: United Nations estimate updated in some cases with recent census data. United Nations (U.N.). *Urban, Rural and City Populations 1950-2000 as Assessed in 1978* (U.N., New York, 1980).

Figure 3.2A Distribution of World Population in Cities of More Than 100,000 Inhabitants, 1980

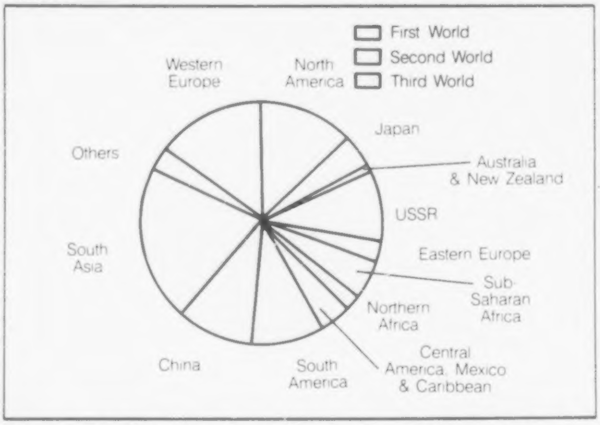


Figure 3.2B Distribution of World Population in Cities of More Than 1 Million Inhabitants, 1980

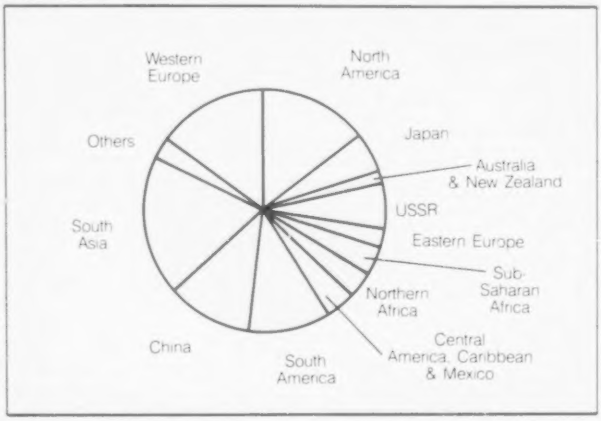
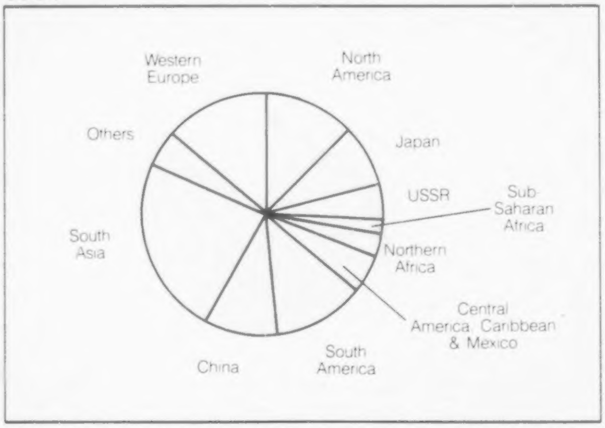


Figure 3.2C Distribution of World Population in Cities of More Than 4 Million Inhabitants, 1980



Source: Derived from United Nations (U.N.), *Estimates and Projections of Urban, Rural and City Populations, 1950-2025: The 1982 Assessment* (U.N., New York, 1985)

holdings or are landless laborers (8), and the number of people in these two categories is growing.

Ownership of agricultural land in Latin America tends to be concentrated in a relative handful of very large estates, or "latifundia." More than 80 percent of the agricultural land in seven South American countries (Brazil, Colombia, Ecuador, Peru, Suriname, Uruguay, and Venezuela) is in holdings of more than 50 hectares. Only 2 percent of the farmland in these countries is in holdings of less than five hectares, even though these small parcels constitute between 14 percent and 81 percent of all agricultural holdings, depending on the country (9).

In Asia, by contrast, about 7 percent of the farmland is in holdings of more than 50 hectares; about 45 percent of the land is in parcels of 5 hectares or less, which constitute 90 percent of all agricultural holdings (10). The FAO recently noted that the "high concentration of land holdings continued in many developing countries, especially in Latin America, and was associated with a high degree of rural poverty" (11).

In many regions of the Third World, the relative poverty of rural life and the concentration of employment opportunities in the urban centers have spurred migration from rural areas. Lured by the prospect of work and a better standard of living, rural migrants usually account for a large proportion of annual population growth in the cities (12), although the proportion varies considerably from one urban center to another.

The policies of Third World governments often give priority to urban areas, thereby encouraging rural to urban migration. Many governments set food prices at artificially low levels in an attempt to avoid social unrest in the cities. As well as reducing the cost of living in urban areas, this practice also reduces the profitability of agriculture. These factors work together to attract people to urban centers. Investments in infrastructure (e.g., roads, sewers) and other construction projects are usually concentrated in urban areas, as are government efforts to encourage industrial development.

CONDITIONS AND TRENDS

URBAN SETTLEMENTS IN THE THIRD WORLD

Over the past several decades, the most striking demographic feature of most of the 120 or so Third World nations has been the rapid population growth of urban areas. (See Figures 3.1A and 3.1B.) Rapid urbanization has been sustained by the combination of high rates of natural population increase (which are also responsible for the absolute population increases in rural areas) and rural-to-urban migration. The relative contribution of each to urban population growth varies, but in the majority of cities natural increases are the primary contributing factor. However, the two sources are intertwined, for a large proportion of those leaving the countryside are in their reproductive years and therefore may be partly responsible for the high rates of natural population increase in urban centers.

In many nations, urban population growth has not been uniform. Many, if not most, of the migrants from rural areas have been settling in one or two major cities, which are the hubs of economic activity. (See Box 3.2.)

The increasing concentration of people in urban centers has strained the capacity of most governments to provide basic services. Illegal settlements are common, and shortages of adequately paying jobs have created large pockets of urban poverty. In addition, levels of air and water pollution in the urban centers of the Third World often surpass those of the heavily industrialized regions of the First World. (See Box 3.3.) Almost without exception, city governments lack the personnel, resources, and power even to begin addressing these problems, and national governments tend to give low priority to the living conditions of the urban poor.

Although urbanization has been widespread in the Third World, its manifestations vary among countries, as do its causes. Moreover, generalizations about population movements mask recent changes that suggest a deceleration, and perhaps a reversal, of the concentrated growth of some dominant urban centers.

Latin America

With 65.3 percent of its population living in cities in 1980, Latin America is the most urbanized of the three regions of the Third World. In 1985, four urban centers (Mexico City, Sao Paulo, Rio de Janeiro, and Buenos Aires) had populations exceeding 10 million, placing them among the world's 15 largest urban agglomerations. In all, one in four Latin Americans lives in a city with a population of at least 1 million.

Trends in Latin America exemplify the general relationship between levels of economic development and levels of urbanization found in most non-communist countries of the Third World. Between 1960 and 1982, the economies of Mexico, Colombia, and Brazil were among the most rapidly growing in Latin America; these countries also experienced the greatest increase—between 17 and 24 percent—in the proportion of the population living in urban areas. In contrast, economic growth was slow in Argentina, Uruguay, and Chile, and the pace of urbanization in these "southern cone" nations was modest during this 22-year period.

Other factors apart from economic activity may be contributing to the slowing of urbanization in the southern cone nations. With about 36 percent of the population living in cities with a million or more residents, Argentina, Chile, and Uruguay are among the most urbanized countries in the world. The highly concentrated populations in these countries, as well as in southern Brazil, result from events that began during the late 1800s and early 1900s, when the coasts of South America were the primary destinations of Europeans emigrating to the continent. The system of land tenure practiced in South America discouraged settlement in rural areas, as did the poor transportation network. Investment was concentrated along the coast, stimulating development of industry and its supporting infrastructure—ports, railroads, and urban services. Consequently, the populations of Buenos Aires and Rosario in Argentina, São Paulo and Rio de Janeiro in Brazil, and Montevideo in Uruguay swelled during the late 1800s and early

Table 3.1 Distribution of the World's Population in Urban Areas by Region, 1960 and 1980

	Population (millions)		Population In Urban Areas[a] (percent)		Population in Cities with 100,000+ Residents (percent)		Population in Cities with 1 million+ Residents (percent)	
	1960	1980	1960	1980	1960	1980	1960	1980
Third World								
Africa[b]			**18.4**	**28.7**				
Eastern Africa	76.0	136.7	7.4	15.7	2.7	8.4	0.0	3.1
Middle Africa	34.9	54.6	18.2	34.4	7.1	18.7	0.0	9.7
Northern Africa	65.1	108.2	30.0	44.1	19.9	25.0	9.7	14.6
Southern Africa	20.8	32.8	42.2	49.2	22.8	23.0	6.3	13.0
Western Africa	80.7	143.8	13.4	22.8	5.6	15.8	0.0	5.5
Latin America[b]			**49.3**	**65.3**				
Caribbean	20.4	29.5	38.7	52.3	19.1	28.8	7.1	15.6
Central America and Mexico	49.5	92.3	46.7	60.7	23.1	37.2	10.5	22.6
Tropical South America	116.1	198.0	46.1	65.8	24.7	41.5	14.3	26.2
Southern Cone of South America	30.7	42.3	72.7	82.4	46.7	54.2	32.7	35.9
Asia[b]			**20.6**	**26.6**				
China	667.3	1,002.8	16.8	20.3	11.4	11.0	6.6	7.0
Other East Asia (not including Japan)	39.7	63.0	36.3	60.4	26.1	49.1	15.9	32.1
South Asia	864.5	1,408.2	18.3	25.4	9.7	15.9	4.0	8.2
Second World								
USSR	214.3	265.5	48.8	63.2	25.6	36.2	6.0	14.0
Eastern Europe	116.7	134.9	44.5	56.3	19.5	26.4	8.0	10.4
First World								
Western Europe	308.4	349.1	66.6	76.8	42.9	48.2	22.6	25.7
North America	198.7	251.9	69.9	73.8	49.5	56.3	28.7	34.7
Japan	94.1	116.7	62.5	76.2	30.5	45.6	21.7	27.0
Australia and New Zealand	12.7	17.9	79.8	85.8	54.8	69.1	31.7	47.0
World[c]	**3,013.8**	**4,453.2**	**33.6**	**39.9**	**19.9**	**24.7**	**9.9**	**13.6**

Notes:

a. Percentages in this column are not comparable due to use of different definitions of an urban population in each country.

b. Countries included in list of nations within each of the African, American, and Asian categories are the same as those used by the United Nations. Europe is divided into two categories: Eastern Europe (Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, and Yugoslavia) and Western Europe (all other countries).

c. Columns do not add to world totals since figures have been rounded and Melanesia and Micronesia were not included.

Source: United Nations (U.N.), *Estimates and Projections of Urban, Rural and City Populations, 1950-2025: The 1982 Assessment* (U.N., New York, 1985).

Box 3.1 The Myth of International Urban Comparisons

Comparisons of national levels of urbanization (the proportion of the population living in cities or metropolitan areas) can be more deceiving than informative. For example, using its definition of "urban center," India is largely a rural nation, with only 24 percent of its own population residing in cities in 1981. In contrast, Peru, by its own definition, is much more urbanized than India. According to U.N. figures for 1985, about two thirds of the people in Peru live in cities. Were India to use Peru's definition of urban center—a settlement with at least 100 occupied dwellings—it would immediately become one of Asia's most urbanized nations. Using this definition would also significantly change urbanization statistics for Asia, because India is the continent's second most populous nation.

Obviously, India and Peru use vastly different criteria to classify cities, towns, and villages. According to the Indian government, an urban center has 5,000 or more inhabitants and, in addition to fulfilling other criteria, must have an adult male population that is employed predominantly in nonagricultural work. Most nations use population thresholds to identify urban centers, but these thresholds range from 100 to 50,000 inhabitants. Some nations do not even consider population size; but instead, identify urban centers as those settlements that have been designated as municipalities or centers of local government. As a result, comparisons among nations often contain little meaningful information.

An alternative to using national estimates of levels of urbanization is to compare percentages of total populations in cities with 100,000 plus or 1 million plus residents. Here the same criterion is used for each country, but comparisons made on this basis also pose problems. They often employ U.N. statistics (used for Table 3.1, main text), which may be extrapolated from older data because many nations have not taken censuses in recent years. These extrapolations rarely identify cities with population levels of 100,000 or 1 million since the last census. It is unlikely, for example, that China, the world's most populous nation, has only one city with a population of 100,000 to 249,999 residents, as reported by the United Nations in 1985. U.N. figures are often at odds with those reported by other sources. In addition, the U.N. data drawn from the report on which Table 3.1 is based greatly overestimate the proportion of many small nations' or territories' populations living in cities of 100,000 or more inhabitants. For these reasons the data on urban populations in this chapter supplement the U.N. data with national censuses and independent analyses where possible.

1900s, with rates of growth exceeding those experienced during recent decades.

A high proportion of Latin America's industry is concentrated in relatively few "core-regions." Three of the most prominent are the La Plata/Buenos Aires/Campana/Zarate/San Nicholas/Rosario/San Lorenzo region in Argentina, the triangle of Rio de Janeiro/Sao Paulo/Belo Horizonte in Brazil, and Mexico City/Toluca/Cuernavaca/Puebla/Queretaro in Mexico. Although the general trend in Latin America's large cities has been for much of the new and expanding industry to be within or near city centers, in recent years industrial and commercial employment has grown more rapidly outside the inner cities. Some central cities have been growing more slowly than suburban rings (or even losing population), and some cities beyond the commuting range of the largest centers have grown more quickly than the metropolitan areas.

The central city, or Federal District, of Buenos Aires, for example, lost population during the 1970s, while the rest of the Greater Buenos Aires Metropolitan Area experienced a population increase of 30 percent. Overall, however, the metropolitan area's share of Argentina's population increased only 0.1 percent during the 1970s, compared with 2 percent during the previous decade. Population growth is slowing in Peru's Lima-Callao area as well. With an estimated 4.4 million inhabitants in 1981, Lima-Callao was among the slowest-growing urban centers with 50,000 or more residents, according to figures for 1972 to 1981.

The rate of population growth in the central city of Sao Paulo has been eclipsed by the increase in the surrounding metropolitan area and, more recently, in cities outside Greater Sao Paulo (13). Comparable trends are evident in the Mexico City Metropolitan Area. Although its population continues to increase, the Federal District has declined in terms of its share of the total population of the Mexico City Metropolitan Area. Relative declines in the Federal District's population, as well as in its share of the metropolitan area's industrial and commercial activity, are expected to continue (14). Moreover, various cities near, but not within, the metropolitan area grew more rapidly during the 1970s than did the metropolitan area itself. Although Mexico City continues to be the primary target of rural-to-urban migration in Mexico, evidence suggests that its attractive power has diminished somewhat. Between 1940 and 1950, 49 percent of all migrants moved to Mexico City; during the next decade, the figure dropped to 42 percent (15).

Contrasting with the pattern of urban growth in the rest of Latin America is the situation in Cuba. Since the mid-1960s the proportion of the urban population living in Havana, the capital and much the largest city, has declined. This decline is largely the result of both the agrarian reform implemented after the revolution in the late 1950s and government efforts to stimulate economic and social development outside Havana. Postponement of new housing and infrastructure investments in Havana has also contributed to the decline of the city's economic and demographic dominance (16).

Asia

Aggregate statistics always mask diversity—a limitation to bear in mind when considering population distribution in Asia, where over two thirds of the population lives in two countries: China and India. Overall, Asia is less urbanized than Latin America, but it does contain nine urban centers with 5 million or more residents: three in China, three in India, and one each in South Korea, Indonesia, and the Philippines.

During the 1960s and 1970s, urbanization proceeded most rapidly in the resource-rich and more economically advanced nations of Asia. Saudi Arabia, South Korea, and Iran underwent the most dramatic transformations; the urban proportion of their total populations increased a third or more between 1960 and 1982. In Saudi Arabia, much of this change is attributed to immigration, including a large influx of temporary workers. In Bangladesh, Nepal, Burma, India, and other poor Asian nations, the pace of urbanization was much slower, even though some of these countries, including Bangladesh and Pakistan, registered substantial increases in manufacturing output during the last two decades.

A mix of demographic changes is occurring in India, although it is not readily apparent in national data. Among India's 12 cities with a million or more inhabitants as of 1981, Lucknow, Kanpur, and Calcutta appear to be experiencing net out-migration, but Bangalore has been growing rapidly. Patterns of urban population growth in India, unlike those elsewhere in the Third World, seem to be less tied to the large urban centers. For example, a demographic study of cities in a relatively rich, urbanized region and cities in a relatively poor, largely rural region found no clear correlation between the size of urban centers and their rates of growth (17). During the 1970s, India's fastest growing cities were those with a population of less than 500,000 in 1971. Many of these cities, which tended to be state capitals, mining centers, or single industry towns, were located far from India's most densely populated regions. Other signs of deconcentrating urban population were evident in such large metropolitan areas as Bombay, Calcutta, and Hyderabad. Cities outside, but near, these metropolitan areas have been growing more rapidly than the central cities (18).

In China, population movements are greatly influenced by the government. Between 1961 and 1976, for example, the country underwent government-imposed de-urbanization, through forced resettlement and strict control of access to jobs, housing, and food. During this period, peasants were recruited to work in industry, but their dependents were not allowed to live with them in their city of employment, a practice that was used by colonial governments in sub-Saharan Africa. Since 1977, however, China's urban population has grown rapidly, with rural-to-urban migration playing a larger role than natural increase. The Chinese government has officially sanctioned the return to urban areas of the millions of people who had been removed to the countryside during the previous period (19).

Africa

Africa has long been the least urbanized of the world's continents, despite a rich and varied (although poorly documented and often poorly understood) urban history that stretches back centuries in many nations. Its largest city is Cairo in Egypt, which, according to some sources, had more than 10 million inhabitants in 1985; Lagos in Nigeria is the second largest urban center, with an estimated population of 5 million in 1985 (20).

In the majority of sub-Saharan nations, at least 75 percent of the population lived in rural areas in 1980, and

Box 3.2 City Primacy within National Economies

Abidjan (Ivory Coast): In 1978, some 70 percent of all economic and commercial transactions were said to take place in Abidjan, which contained around 15 percent of the national population.

Bangkok (Thailand): The metropolitan area contained 86 percent of gross national product (GNP) in banking, insurance, and real estate, 74 percent of manufacturing, 61 percent of government expenditures in public administration and defense, and one third of national gross domestic product (GDP) in the early seventies. At that time, it had 10 percent of the national population.

Lagos (Nigeria): In 1981, the metropolitan area handled over 40 percent of the nation's external trade, accounted for over 57 percent of total value added in manufacturing, and contained over 40 percent of highly skilled manpower. It contains about 5 percent of the national population.

Lima (Peru): The metropolitan area accounts for 43 percent of GDP, four fifths of bank credit and consumer goods production, and more than 90 percent of capital goods production in Peru. It contained about 27 percent of the national population in 1981.

Managua (Nicaragua): A report in 1983 suggests that enterprises in Managua account for 38 percent of the nation's GDP. It contains about 25 percent of the national population.

Manila (Philippines): The metropolitan area produces one third of the nation's GNP, handles 70 percent of all imports, and contains 60 percent of all manufacturing establishments. In 1981, it contained about 13 percent of the national population.

Mexico City (Mexico): In 1970, it contained 30 percent of total employment in manufacturing, 28 percent of employment in commerce, 38 percent of employment in services, 69 percent of employment in national government, 62 percent of national investment in higher education, and 80 percent of research activities. In 1965, it contained 44 percent of national bank deposits and 61 percent of national credits. In 1970, it contained about 24 percent of the national population.

Nairobi (Kenya): In 1975, it contained 57 percent of all Kenya's manufacturing employment and, in 1974, 67 percent of its industrial plants. By 1975, Nairobi and its industrial satellite, Thika, contained 61 percent of all industrial wage employment. In 1979, Nairobi contained 5 percent of the national population.

Port au Prince (Haiti): Approximately 40 percent of the national income is produced within Port au Prince. It monopolizes all urban economic activities. The centralized political and administrative system and development policies geared to the manufacturing sector have contributed to this situation. Only some 14 percent of the national population lives there.

Rangoon (Burma): Located at the center of the national transport and communications network, Rangoon is the economic, political, and administrative heart of Burma. It is the dominant tertiary service center, and virtually all the import and export trade passes through its port. More than half the national manufacturing industry is said to be located there. In 1981, it contained 6 percent of the national population.

São Paulo (Brazil): In 1980, Greater São Paulo contributed over 40 percent of Brazil's industrial value-added manufacturing and one quarter of net national product. In that same year, it contained about one tenth of the national population.

Source: Adapted from Table 2 in J.E. Hardoy and D. Satterthwaite, "Government Policies and Small and Intermediate Urban Centres," in *Small and Intermediate Urban Centres: Their Role in Regional and National Development in the Third World*, J.E. Hardoy and D. Satterthwaite, Eds. (Hodder and Stoughton, London, 1986).

most were working in agriculture. Despite their largely rural character, many of these nations offer the most striking examples of urbanization in recent decades. For example, since 1950, the populations of Nairobi in Kenya, Abidjan in the Ivory Coast, and Dar es Salaam in Tanzania have increased more than sixfold (21). During the same period, the population of Lagos grew more than sixteenfold (22); and the number of people living in Nouakchott in Mauritania is estimated at more than 40 times the 1965 population (23). For most of these cities and others that have experienced marked population increases, migrants account for most of the rapid growth since the 1950s, even though sub-Saharan Africa has some of the world's highest rates of natural increase.

This rapid growth in urban population has often occurred in spite of economic stagnation. For example, Chad, Zaire, the Central African Republic, and Ghana experienced little or no economic growth during the 1960s and 1970s, but the proportion of their populations living in urban areas increased at least 12 percent between 1960 and 1982. This population growth was partly a response to the removal of population restrictions imposed by former colonial governments and partly to the building of the necessary institutional structure after independence was gained. By focusing on cities, government-funded efforts to spur industrial development have also contributed to rapid urbanization.

Such factors are evident in Tanzania's urban population growth. In 1952, 27 percent of the inhabitants of the colonial capital, Dar es Salaam, were non-African, and among the African population, men outnumbered women by a ratio of 1.5:1. This imbalance was the result of colonial policies that strongly discouraged women and children from living with their husbands and fathers in urban centers. Tanzania's independence triggered a large wave of migration to cities, with women comprising a significant part of the influx. By 1967, the imbalance between the sexes had been reduced to a ratio of 1.2:1 (24).

Trends in the country of South Africa stand out as exceptions to those in the rest of sub-Saharan Africa, as well as to those in the northern part of the continent. South Africa's system of apartheid accounts for this difference. There the majority of the population is denied basic economic, political, and social rights on the basis of race. As a result, most South African residents are prevented from moving from areas of high unemployment and the predominantly rural "homelands" to which many have been forcibly relocated.

Patterns of population movement in northern Africa are more akin to changes taking place in Asia and Latin America. For instance, between 1970 and 1982, Algeria, Tunisia, Libya, and Morocco had rates of growth in gross domestic product and manufacturing output that were among the highest in Africa. These countries were also among the leaders in terms of increases in the proportion of the national population living in urban areas. In Libya, for example, this proportion increased 35 percent.

From the perspective of the entire continent, little can be concluded about trends in the growth rates of cities in different population categories. The data base is too poor for such broad trends to be discernible, but some evidence suggests that the largest cities within some nations may be attracting a lower proportion of new economic investment. During the decade 1969–79, Kenya's two largest cities, Nairobi and Mombasa, had slower rates of population increase than any of the other 16 urban centers that had more than 20,000 residents in 1979. Recent reports also suggest that Cairo's population growth has begun to slow considerably (25). With the scanty evidence available, however, it is not possible to determine whether parts of Africa are moving toward deconcentration of the urban population.

Box 3.3 The Environmental Problems of Cities

The legacy of death and injury that resulted from the chemical leak in Bhopal, India, in 1984 has focused global attention on the environmental problems of Third World cities. More serious than tragedies such as Bhopal, however, are the environmental insults suffered daily by city residents. In many cities, high concentrations of heavy metals have been found in drinking water supplies, and a growing number of case studies have documented the high frequency of pollution-related illnesses. Because of the lack of enviromental regulations or the lack of enforcement, such problems are not limited to cities with high concentrations of industry. Communities with only a few factories have had their water supplies polluted as a result of careless emissions, a problem that is often compounded by the inadequacy or complete lack of local sewage and drainage systems. The toll of such environmental damage usually falls disproportionately on the urban poor, who tend to live in the most polluted sections of cities and who, because of the lack of basic services, often must draw their drinking water from polluted rivers.

Although it may originate in cities, environmental pollution and the damage it inflicts are not confined to city boundaries. Air pollution from heavy concentrations of industry has caused serious crop damage many miles away from the sources of pollutants, and disposal of wastes into local waters has destroyed coastal and river fisheries. In addition, the lack of effective planning has allowed urban developments to consume productive farmland, reducing the agricultural base for satisfying national food needs and displacing agricultural workers who then must move to cities to find work. Pollution, urban sprawl, and the growing urban demand for raw materials such as fuelwood have aggravated problems of deforestation and destruction of the natural landscape, resulting in environmental losses that will be felt for years to come.

Some of the serious enviromental problems found in the cities of the First and Second Worlds are the result of past carelessness and inadequate environmental controls. Although First World cities usually have the necessary infrastructure, the deterioration of this infrastructure through aging is a frequent problem. Cities cannot always afford the necessary investments to repair sewage systems, roads, etc., particularly if the city tax base has been declining as businesses and richer households move out. As in the Third World, environmental problems that originate in the cities of the First and Second Worlds reach far beyond urban boundaries. For example, most sulfur and nitrogen oxides originate from coal-fired power plants, smelters, and automobiles in urban areas, although the harmful effects of acid deposition are felt primarily in rural areas.

URBAN SETTLEMENTS IN THE SECOND WORLD

The nine nations of the Second World comprise 9 percent of the world population, with the Soviet Union accounting for two thirds of the total population and 95 percent of the total land area. These nations, which are characterized by their centrally planned economies and the political and economic interdependence that has developed under the influence of the Soviet Union, contain no urban centers with a population of 10 million or more. Population distribution is dictated largely by government priorities and programs. The scope of government influence varies among nations, however, as do other factors affecting settlement patterns, including the type and level of development of the industrial, agricultural, and service sectors.

While most Second World nations urbanized rapidly during the 1960s and 1970s, the rate of urban population growth was slow by world standards, even though economic growth is believed to have been relatively high in most countries. As in the First World, low rates of natural increase helped keep growth in urban populations well below the norm for Africa, Asia, and Latin America.

The limited data available suggest considerable economic restructuring during the past two decades. Most countries experienced significant shifts in the relative importance of agriculture, industry, and services in terms of these sectors' contributions to gross domestic product and job creation. The proportion of the labor force working in agriculture declined substantially in most countries, and the proportion working in industry increased substantially. An exception is Albania, the only Second World country in which agriculture is the primary employer. According to estimates for 1981, 61 percent of Albania's labor force was engaged in agricultural work. Yugoslavia represents another exception because of the large proportion of the work force employed in the service sector. In 1980, 36 percent of Yugoslavia's workers had service-related jobs, and 35 percent were employed in industry, according to estimates. In all other Second World nations, the industrial sector's share of national employment was larger than that of the service sector. This distribution of employment contrasts with the First World and some of the richer nations of the Third World, where most jobs are in the service sector. Finally, East Germany has been relatively unaffected by the economic trends that have characterized much of the Second World during recent decades. In 1960, it was the most urbanized, and one of the most industrialized Second World nations, and since then it has experienced smaller changes than most other countries in its economic structure and employment pattern.

The prominence of industry in the Second World is largely a reflection of central economic planning. During the 1950s (and before then in the Soviet Union), development of industry—especially heavy industry—was a high priority. Location of new factories was usually guided by economic logic, which considers such factors as proximity to raw materials and energy sources. Other factors—social, political, and military—also influenced location decisions, however. For example, some industrial development was aimed at reducing disparities between the more industrialized northern nations and their less developed Balkan counterparts, and other development was intended to increase employment opportunities in the poorer, less-urbanized regions of the Second World.

The fact that most or all investment is controlled by the state implies that the state has the means to determine both the form and location of urban development. The relatively low proportion of the Second World population living in cities with 1 million or more inhabitants is striking, considering levels of industrial development, and it may reflect the aim to control urban population growth. (See Figures 3.2A and 3.2B.) The state's demographic influence is particularly apparent in the Soviet Union's ambitious "new town" program. Between 1926 and 1963, more than 800 new towns and cities were built, one third of them on new sites. As of 1980, nearly 30 percent of the Soviet Union's urban population lived in new towns, compared with about 6 percent in Great Britain, which has one of the First World's largest new town programs. In Eastern Europe some 60 new towns have been constructed, but only about 3 percent of the Second World's urban population lives in them.

Urban and economic planning notwithstanding, industrial development and population distribution in the Second World are less uniform than government plans and policies might suggest. Ambitious planning goals to slow or halt the population growth of certain large cities, for example, have not been met. Industrial ministries, agencies, and enterprises have frequently been at odds with territorial or spatial-planning goals, and their interests have usually prevailed. Moreover, the social benefits of steering industry to poor regions have often fallen short of expectations, and the costs of development are often higher than anticipated. As a result, industry tends to remain concentrated in the Second World's traditional industrial heartlands.

From the perspective of the Second World's urban centers, perhaps the two most pressing problems are inadequate housing and pollution. Some nations continue to feel the devastating effects of World War II. Yugoslavia, for example, lost three quarters of its housing stock during the war. Urban population growth and decreasing household size have aggravated housing shortages, but some governments have given this problem a low priority. From the mid-1960s to the late 1970s, governments did increase their support for housing construction, bringing some relief, but they decreased support during the 1980s. Serious problems remain and are likely to worsen if this decrease in government support persists. In all nations except the Soviet Union and Romania, governments have taken steps to counter inefficiency in public housing programs by increasing support for construction of private and cooperative housing. These governments also have encouraged transferring housing ownership to tenants (26).

The Second World's industrial centers also suffer from serious environmental problems, especially in East Germany, Poland, and Czechoslovakia. In some areas, levels of air, water, and noise pollution are among the highest in the world. (See Box 3.3.)

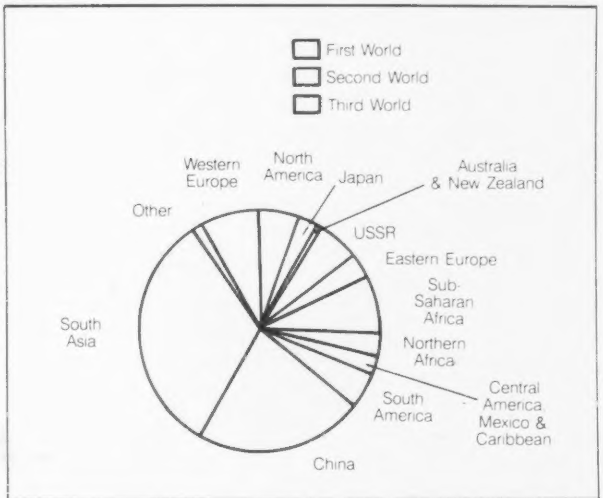
URBAN SETTLEMENTS IN THE FIRST WORLD

Containing one sixth of the world population, the highly urbanized First World dominates the international economy. (See Figure 3.3.) It accounts for three fifths of the world's value-added manufacturing and considerably larger shares of both the service sector and of global research and development activity. Within the First World are three of the world's largest urban agglomerations: New York/northeastern New Jersey and Los Angeles/Long Beach in the United States and Tokyo/Yokohama in Japan, all with populations exceeding 10 million.

In economic and demographic terms, the United States, Japan, and the nations of the European Economic Community tend to dominate. As a whole, the nations of the First World are much more alike than those of the Third World. Largely because of their so-called mature economies, trends in population distribution in the First World differ from those in developing countries that have undergone fairly rapid growth during recent decades. In some First World nations, smaller urban centers and rural areas are accommodating an increasing rather than a decreasing proportion of the population, a trend known as "counter-urbanization."

Moderation and, in some cases, reversal of urban growth disproved earlier predictions of massive urban centers that would contain increasingly larger proportions of a nation's population. In England, for example, London was envisioned as overtaking all the Southeast. Instead, Greater London, which includes most of the contiguous suburbs, has been losing population since the 1940s. Projections for the United States estimated that half the nation's population would reside in three giant metropolitan areas. Recent censuses suggest just the opposite. Rather than contracting, rural areas and smaller urban centers are increasing their share of the U.S. population.

Figure 3.3 Distribution of World Population, 1980



Source: Derived from United Nations (U.N.), *Estimates and Projections of Urban, Rural and City Populations, 1950-2025: The 1982 Assessment*, (U.N., New York, 1985)

The United States

Counter-urbanization is most advanced and best documented in the United States, from both regional and local perspectives. Since 1950, the South and West, which make up the "Sunbelt," have been gaining population at the expense of the North Central and Northeast regions, the traditional industrial heartland that has been given the labels of "Rustbelt" and "Snowbelt." Along with this regional shift has come a reversal of the exodus of blacks from the South to the industrial cities of the North. Since 1970, the South has been experiencing a net in-migration of blacks, who are settling primarily in southern metropolitan areas. Not coincidentally, the nation's fastest-growing urban centers during the first half of the 1970s were in the South and West, while virtually all the large cities in the Northeast and North Central regions were losing population. In these northern regions, the proportion of the population living in urban areas decreased between 1970 and 1980.

As in previous decades, the central cities of metropolitan areas continued to lose population during the 1970s, while surrounding suburbs continued to gain. However, a new element was added to this long-established trend in the United States: on a national scale, the rates of population gain outside metropolitan areas outpaced suburban growth rates.

The United Kingdom

England also experienced considerable redistribution of its population during the 1970s and early 1980s. Migration from England's rural regions of East Anglia, the East Midlands, the Southwest Peninsula, and much of Central and North Wales to the nation's cities has been reversed, breaking a trend that began a century ago. The marked shift in population movement has resulted in a "new map of growth and decline—a map that is almost the obverse of the map of a hundred years ago and that is dramatically different from the map of even 20 years ago" (27). While some of the population shift of the 1970s and early 1980s was directed toward the planned developments, or "new towns," around major metropolitan areas, most of the movement was "into genuinely rural areas, outside the commuting spheres of the big cities" (28). The three regions that experienced the most rapid rates of population increase between 1971 and 1981 contain no large urban concentrations.

Population changes in England's metropolitan areas resemble the changes that have taken place in the United States during recent decades. Population growth was focused on the suburbs in the 1950s and on the outer metropolitan rings in the 1960s, when central cities sustained absolute losses in population. Also during the 1960s, England's central cities lost half a million jobs, while suburbs and inner metropolitan rings increased their share of employment. Absolute population losses continued in the central cities during the 1970s. Generally, the larger the city, the greater the population loss sustained. In recent years, however, population dispersal seems to have abated. Signs of population concentration in the Southeast have reappeared, and the movement of people out of central cities may have slowed.

Europe

Population deconcentration is also evident in West Germany, Switzerland, Austria, and the Netherlands. For example, the Netherlands' three largest cities—Amsterdam, Rotterdam, and the Hague—lost about 110,000 residents to suburban locations between 1971 and 1974. In Sweden and France, however, major metropolitan areas are continuing to grow, largely because of the influx of foreign immigrants. In southern Europe, the central cities and inner suburbs of metropolitan areas are also continuing to grow, but rates of population increase have slowed. During the early 1970s, outer metropolitan rings were growing twice as fast as the metropolitan cores (29). Significant urban-to-rural migration was not evident in southern Europe during the 1970s, but Italy appears to be experiencing a reversal of the migration from the rural regions of the South to the industrial centers of the North. Economic stagnation in the northern industrial triangle dominated by Genoa, Turin, and Milan seems to have prompted the return of migrants to the homes they left during the 1960s.

Canada, Australia, and Japan

The populations of other First World nations are also decentralizing, some more so than others. Recent census data for Canada indicate a pronounced trend toward population dispersal. In the mid-1970s, medium-sized and small cities were the primary targets of the country's internal migration; more recently, Canada's rural areas have been gaining population and, for the first time, are experiencing net in-migration. The growth of Canada's small towns and villages is attributed to suburbanization and to the movement of people to communities well beyond the boundaries of metropolitan areas. In Australia, foreign immigration continues to underpin the growth of large cities, but movement away from major urban centers is also apparent. Japan has begun to show signs of deconcentration, with population growth rates of suburbs exceeding those of central cities in the nation's largest metropolitan areas. In addition, an analysis published in 1978 notes "a sudden and precipitous drop in net migration into Japan's three major metropolitan regions" (30). At about the same time, net migration to peripheral regions, including outlying islands, increased.

CAUSES AND EFFECTS OF DECENTRALIZATION

Deconcentration is the result of many factors, ranging from economic restructuring to lifestyle choices, whose relative significance is difficult to establish. It is certain, however, that advances in communication and transportation have facilitated recent changes. Telephones and computers, especially, have diminished the advantages that traditionally accrued to a central city location, while increasing the range of options for siting businesses or residential developments. Population dispersal in the First World reflects the ability to live and work in rural areas without abandoning an urban lifestyle.

Many businesses in the service sector are less dependent on city infrastructure and traditional government services than are their counterparts in manufacturing. But the manufacturing industry is also loosening its ties to the city. Decentralization of operations, cheaper land and labor, quality-of-life considerations, and a host of other factors have increased the attractiveness of rural locations for manufacturers.

These conditions contrast sharply with those in the Third World and even the Second World. One difference is the prominence of industry in the Second and Third Worlds, compared with the continuing rise of the service sector in the First World. The concentration of industry and manufacturing jobs in cities has helped fuel urban population growth in the Second and Third Worlds; job creation in the First World's service sector has contributed to population deconcentration.

Ironically, population dispersal in the First World is accompanied by problems similar to those that result from rapid urban population growth. In the core regions of the Third World, unmanageable growth has overwhelmed the ability of local governments to provide the most fundamental services for much of the population. First World cities that have suffered population losses are also finding it increasingly difficult to finance public services. The exodus from major central cities is largely composed of people who are better educated and are in the higher income brackets. As a result, many central cities contain disproportionate numbers of the elderly and poor. Significant losses of people in the middle- and higher-income groups diminish local demand for commercial goods and services, discouraging new business investment. This combination of influences erodes the local tax base and, in turn, threatens the provision of basic services, further discouraging new investment.

The ills of declining cities tend to be borne disproportionately by the disadvantaged, including racial and ethnic minorities. This economic and demographic phenomenon, which has been called the "entrapment process," is illustrated by the unemployment and housing inadequacies that beset large segments of the population in many First World cities. Such inequities are believed to be major causes of the social unrest and violence that have occurred in some major urban centers. The relationship between such problems and population deconcentration is underscored in a study of population and social trends in England between 1971 and 1981. According to the study, the faster the rate of population decrease experienced by a city, the greater the extent of deprivation at the end of the ten-year period. In contrast, areas with the fastest population growth were characterized by high average incomes and other favorable economic and social indicators (31).

This study of circumstances in England and observations of trends in other First World nations imply increasing economic and social segregation among regions and between the cities and the countryside.

WHAT INFLUENCES URBAN CHANGE?

Comparisons of categories of countries demonstrate how economic conditions influence population distribution and the quality of life of the general populace. In Third World nations, the very rapid growth of urban centers is, in part, the product of migration to areas where job opportunities are concentrated. This process generates its own economic momentum, however, by further concentrating the demand for goods and services. One consequence is a broadening of economic disparities between major urban centers and rural areas, where the bulk of the Third World population lives. The lack of purchasing power among rural residents, most of whom either farm subsistence plots or are landless laborers, provides no incentive for the investment necessary to undergird development. The few exceptions to this rule are areas that have experienced rapid growth in agricultural production and are characterized by relatively equal distribution of land ownership (32), and by little, if any, government-induced distortion of agricultural prices.

The counter-urbanization that is occurring in the First World can also be explained to some extent by distribution of economic activity and income, as discussed in the previous section. In addition, relatively equal distribution of wealth and relatively high average incomes help explain the more dispersed pattern of urban development in First World nations, compared with the dominance of only one or two major urban centers in developing countries.

Government policy measures have also influenced population distribution, especially in nations with centrally planned economies. Consider, for example, P'Yŏngyang, the capital of North Korea. Heavily damaged during the Korean War, P'Yŏngyang was rebuilt according to government plans, and its population growth has been controlled. With a 1980 population of 1.7 million, the city does not suffer from the overcrowding that besets Seoul, the capital of neighboring South Korea. The Seoul metropolitan area has grown rapidly since World War II and is now believed to contain 13.7 million people (33).

Government goals and policies have also influenced urban growth and development in China. The Chinese government has deliberately sought to achieve a dispersed pattern of industrial development, reflecting the desire to develop the country's interior and, until recently, to reduce the concentration of industry on its vulnerable eastern coast (34).

The impact of government investment on population distribution is evident in countries with mixed or market economies as well. The U.S. government's expenditures for national defense and its space program helped promote the shift of population and economic activity to the South and West. In India, expenditures for defense have contributed to the rapid growth of Bangalore, the site of much defense-related industry (35).

Beyond the control of local, regional, and even national governments are the influences of the world market, which can have a significant influence on economic activity and, therefore, on population trends. London's rapid population growth during much of the last century, and its decline since the 1940s, cannot be dissociated from the city's changing role in the world market. The rapid population growth of São Paulo and Seoul during recent decades must also be considered in the context of international developments.

Certain countries—most notably, China, from the 1950s through the early 1970s—have sought to insulate their economies from world market forces. Groups of countries such as the European Economic Community, with regard to agriculture, and members of the Council for Mutual Economic Assistance, have also sought to do so. But no economy is completely impervious. The influences of trade protectionism in the First World and resource cartels such as the Organization of Petroleum Exporting Countries (OPEC) are difficult to avoid. Similarly, the rising foreign debts of many Third World countries also have the potential to affect local employment, living conditions, and population distribution. (See "Recent Developments," below.)

Enumerating some of the economic, social, and political factors that influence the pattern of human settlements indicates the complexity of population change. But these factors are not explicitly taken into account in United Nations projections of future levels of urbanization or population size in specific Third World cities. Instead, the projections are essentially based on the extrapolation of past trends in population growth, and they should therefore be regarded with considerable skepticism.

FOCUS ON: HOUSING THE THIRD WORLD URBAN POOR

In most Third World cities, between one quarter and one half the population lives in popular settlements: illegally built settlements where the inhabitants manage construction of the houses, often undertaking much of the work themselves (36). In such large cities as Rio de Janeiro, São Paulo, Lima, Bogatá, Caracas, Mexico City, Bangkok, Bombay, Calcutta, Madras, Cairo, and Lagos, more than 1 million people reside in popular settlements.

Because these developments are illegal, there is usually little or no public provision of basic services: water supply, sewage and drainage systems, garbage removal, roads, electricity, transportation, schools, and medical care. The few services that do exist are not usually the result of government action, but rather, the efforts of local residents. Not surprisingly, such poor living conditions give rise to serious health problems, many of which could be easily prevented. The few studies that have examined health conditions in popular settlements have found respiratory and intestinal diseases (the result of poor sanitation and contaminated drinking water) to be endemic (37). Accidents also inflict a considerable toll. Fires are common because most dwellings use kerosene stoves or fuelwood for cooking and heat.

To diminish the threat of eviction, many popular settlements are situated on land unfit for permanent habitation and prone to environmental damage. In Rio de Janeiro, La Paz, Guatemala City, and Caracas, developments are located on the sides of landslide-prone hills. In other cities (for example, Recife, Monrovia, Guayaquil, Lagos, Bombay, Port Moresby, Delhi, and Bangkok), settlements stand on land subject to flooding or inundation by tidal waves, or they may be situated on sandy desert land (as in Lima and Khartoum) or in the most polluted districts of inner cities.

Simple logic guides the location of squatter settlements, those settlements built on public or privately owned land without the owner's approval. Inhabitants build where they believe they have the best chance of escaping the bulldozer, yet within a reasonable distance from their jobs. They avoid parcels of land well-suited to residential development, which are often held by individuals or institutions who let their land stand idle in anticipation of speculative gains. Settling on these properties would mean almost certain eviction. Instead, the urban poor are relegated to the most undesirable locations. This kind of haphazard development results in a patchwork of high- and low-density housing and business development that makes the planning and provision of public services difficult and costly.

The rapid growth and spread of popular settlements exacerbate the social and economic segregation characteristic of Third World cities and perpetuate the disparities that characterized colonial rule. While the rich reside in the choicest and best-serviced urban locations, the poor are forced into the worst sites. Despite their low status, the poor are an integral part of the urban economy, providing a market for cheap goods and services and serving as a pool of cheap labor. Moreover, popular settlements account for most of the new housing in Third World cities, a fact that has changed the way some governments regard these developments.

Besides rapid increases in urban populations, the widespread growth of popular settlements reflects the decreasing role of tenements in large Third World cities. Once the primary source of low-income housing and beset by many of the problems common in popular settlements, tenements still may house tens of thousands of families today, but they are becoming less lucrative for their owners. For example, owners of inner-city lots have found it more profitable to raze tenement buildings and replace them with high-income apartments or with commercial developments. In addition, some governments have introduced regulations to upgrade slum housing and imposed rent control laws that discourage private investment in tenement housing.

Government attitudes toward illegal settlements range from benign neglect to active opposition and to acceptance and gradual provision of some services. Residents of illegal settlements may experience the entire range of these attitudes over time because of changes in government leadership and even changes in the views of one administration. Whether residents eventually secure tenure depends on many factors. But the residents of some settlements that are situated on public lands have been able to exert political pressure that has resulted in government guarantees against eviction. On occasion, residents have succeeded in securing ownership and provision of some public services. Some governments have even encouraged squatter invasions, as in Peru between 1968 and 1971, and in Turkey, where the government passed special legislation in support of squatter settlements in 1966.

Experience in Chile typifies how government attitudes can change. Under the administration of Salvador Allende from 1970–73, government agencies supported squatter invasions. Under the military regime that replaced the Allende government in 1973, however, squatter invasions have been actively opposed. Because they can comprise a significant portion of the electorate, low-income residents in cities and nations with representative forms of government stand a better chance of securing support, or at least tolerance, for their settlements than do those who live under autocratic rule.

Some popular settlements have the approval of the owner of the occupied land who receives payment from the inhabitants. Owners of subdivided properties rarely conform with local zoning requirements and housing codes. In most instances, residents purchase a lot and build their homes: the owner usually does little or nothing in the way of building roads or providing other basic services. An example of this kind of settlement, ironically named the "Garden Flower of Spring," is on the edge of metropolitan São Paulo. The buyers not only had to build their houses but they also had to develop roads and paths and construct a bridge to connect the subdivision to a public road. These infrastructural improvements increased the land value, allowing the owner to sell the remaining lots at substantially higher prices (38).

Governments have tended to be more accepting of illegal subdivisions, occasionally legalizing their status and providing some basic services, while still repressing or destroying settlements. Such was the attitude of the Delhi government during the 1970s and the governments of Mexico City and Bogota.

Recognizing the importance of popular settlements to local economies, some governments have changed their attitudes and approaches to these illegal developments. Some cities—such as Karachi in Pakistan, Lusaka in Zambia, and many urban centers in Peru and Tanzania—have begun to give those living in popular settlements the legal right to be there. Legal recognition has often been accompanied by the provision of basic infrastructure and services. An increasing number of governments are realizing that popular settlements are a cheap alternative to publicly funded housing developments. And on occasion, governments have released unused and underused property in an attempt to ensure that there are legal and affordable alternatives to squatter settlements. This approach has been used in Managua, Nicaragua, and in several Tunisian cities to control urban growth and improve the quality of local housing. In addition, authorities in some cities have concluded that existing building and planning regulations are out-dated and unrealistic, a situation that has encouraged violations. Government projects that have experimented with alternative ways of improving housing conditions for the urban poor have found that policies aimed at reducing the cost of building materials can lead to desirable innovations. Other projects have demonstrated that providing small, flexible, easily obtainable loans can be a boon not only to housing improvements but to construction as well.

While numerous projects have demonstrated the merits of improving housing conditions, none yet demonstrates the breadth of effort needed to make significant progress. Few city and national governments recognize that action is necessary in a broad range of areas—and that a comprehensive approach requires an institutional framework. Not only should building and planning codes be waived in a few innovative projects, for example, but they should be replaced by a flexible and realistic set of guidelines that promote health and safety, the intended goal of such regulations. Loan programs evaluated in pilot projects should be expanded and placed under the charge of a city-wide agency. For most urban governments, a major hindrance is the lack of resources, authority, and personnel necessary to ensure steady improvements in infrastructure and basic services. Without these necessary elements and broad-scale programs to address the full range of housing problems and their causes, the situation in Third World cities is likely to worsen.

RECENT DEVELOPMENTS

THE IMPACT OF THIRD WORLD DEBT

A large number of Third World nations, particularly in Africa and Latin America, are currently in a state of economic recession, stemming largely from high external debts, large oil import bills, and the deteriorating terms of trade for most of their primary commodity exports. Most of the countries have responded to their economic problems, sometimes under pressure from the International Monetary Fund or the World Bank, with austerity programs involving monetary restrictions and decreased public expenditures. One important element of this economic crisis is a deterioration in Third World living conditions, particularly in the major urban centers.

The cutbacks in public expenditures have primarily affected investments, particularly in the construction sector and in social services. As a result, the badly needed investments in basic infrastructure and services to improve the living conditions of the urban poor are less likely to be made. The contraction in expenditures (which has also affected the private sector) has in turn led to higher unemployment rates and decreases in real wages and incomes, aggravating the extent and depth of urban poverty.

Despite their relatively advanced state of economic development, Latin American countries have been as badly affected as any others. The impact of the present crisis has been likened to that of the Great Depression of 1929–32. But there is one fundamental difference—this crisis is taking place in heavily urbanized societies. Latin America is caught up in a "recessionary vicious cycle, mainly urban in its manifestations, concentrated above all in the metropolitan areas, which are those requiring the greatest levels of financial resources in order to function" (39). One of its most important symptoms is the magnitude of urban unemployment, which has grown considerably in most countries since 1979 and has doubled in Argentina, Bolivia, Uruguay, and Venezuela. (See Table 3.2.)

Table 3.2 Latin America: Evolution of Urban Unemployment, 1979–84

(Average annual rates)

Country	1979	1980	1981	1982	1983	1984
Argentina	2.0	2.3	4.5	4.8	4.1	4.0
Bolivia	7.6	7.5	9.7	9.4	12.1	13.3
Brazil	6.4	7.2	7.9	6.3	6.7	7.5
Colombia	8.9	9.7	8.2	9.3	11.8	13.5
Costa Rica	5.3	6.0	9.1	9.9	8.5	7.9
Chile	13.4	11.7	9.0	20.0	19.0	18.6
Mexico	5.7	4.5	4.2	4.1	6.9	6.3
Nicaragua	21.4	18.3	15.9	18.5	18.9	19.8
Panama	11.6	9.8	11.8	10.3	11.2	X
Paraguay	5.9	4.1	2.2	5.6	8.4	X
Peru	6.5	7.1	6.8	7.0	9.2	10.9
Uruguay	8.3	7.4	6.7	11.9	15.5	14.5
Venezuela	5.8	6.6	6.8	7.8	10.5	13.9

X = not available

Source: Sunkel, 1985, Reference 39

The unemployment figures are particularly serious given the fact that the poor have almost no accumulated assets of durable goods; there are little or no social security and unemployment benefits; and this increase is over and above massive rates of urban and rural underemployment. In addition, the incomes of those who are still employed have been reduced in real terms by inflation, particularly in Bolivia, Argentina, Brazil, and Peru. In many countries, real wages are lower now than they were a decade and a half ago (40).

The prospects are bleak. The net outflow of financial resources from Latin America to the western industrialized countries is likely to continue in view of the fact that the external debt, standing at $360 million in 1984, is still increasing. The chances of a return to even precrisis levels of economic activity during the remainder of this decade look remote. The decline in urban work opportunities and living conditions may help to slow rural-to-urban migration. But in the absence of radical changes in policy, further deterioration in urban nutrition, health, and living conditions appears inevitable.

URBAN POLICY SHIFTS IN THE UNITED STATES

The early eighties have witnessed a major change in urban policy in the United States and, to a lesser extent, in the United Kingdom. Revitalization of the cities has been a policy objective of most First World governments since the end of the Second World War. In the 1960s and 1970s the U.S. Government pursued area-based programs to tackle urban poverty, unemployment, and deteriorating housing conditions. The current U.S. administration, however, holds the view that major urban problems will be solved only by general economic recovery, not by targeting funds to specific areas.

The main thrust of current policy—known as the New Privatism—is to let the market solve the problems of the urban system. This policy shift reflects a basic change in the government's view of the relationship between cities and the national economy. It is no longer assumed that "national recovery depends upon the prosperity of the large urban centers nor even that it will result in the revival of flagging city economies" (41).

In making the condition of the cities a side effect of economic policy, in a sense the current administration is turning its back on urban settlement problems. Responsibility for dealing with the disruptive effects of economic adjustments has been shifted from the federal to the local level, forcing cities to adapt themselves to changes in the nature and direction of the economy.

References and Notes

1. In this report, "urbanization" is defined as the process by which an increasing proportion of the national population comes to live in urban centers. Thus, growth in urban populations only constitutes increasing urbanization if it is proportionately greater than any growth in the rural population. Care must be taken not to confuse the term with physical growth of urban areas, which is also sometimes described as urbanization.
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36. Popular settlements include both squatter settlements and illegal subdivisions. Both are illegal, but in the case of the latter, the occupation of the land is with the approval of the owner, to whom payment is made. In illegal subdivisions the landowner (or a developer who has bought the land) subdivides the land into building plots without getting permission from city authorities and usually without meeting the codes and norms demanded by local regulations.
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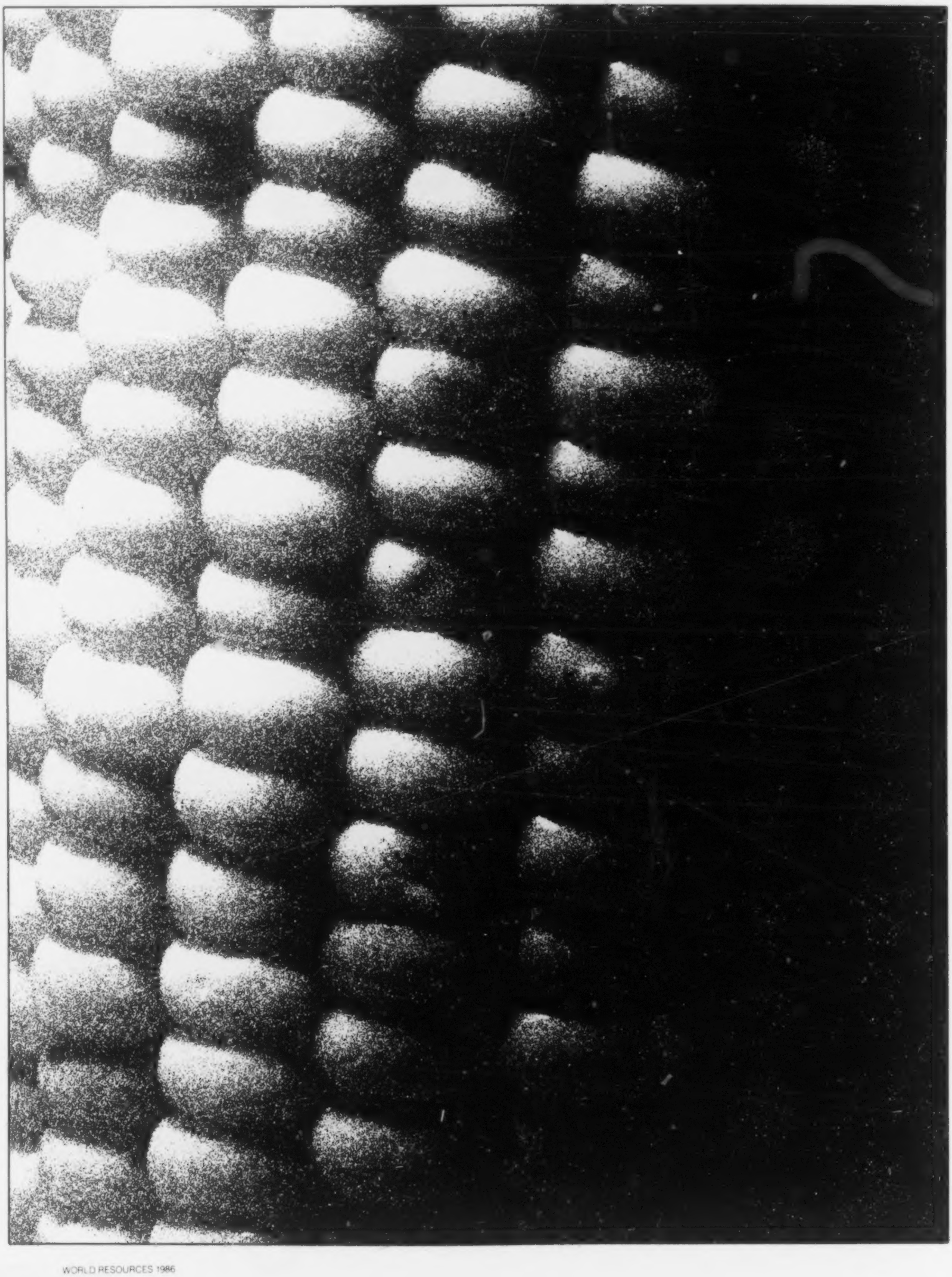
41. R. Boyle and D. Rich, "Urban Policy and the New Privatism in the United States and Britain," *Public Administration Bulletin*, No. 45 (1984).



4. Food and Agriculture

The state of the world's food and agriculture systems in the mid-1980s can best be described as an almost intractable paradox. While humankind was demonstrating once again the planet's awesome ability to produce ever more food and fiber, television sets around the world were revealing pitiful scenes of mass starvation in Africa and record books were disclosing the grim statistics that more people than ever—about half a billion (1)—were living in a state of serious malnutrition.

The mid-1980s saw world food production reach levels so high that many commodity prices plummeted below the actual cost of production, precipitating a wave of farm foreclosures in the United States and ever-increasing levels of state subsidies for farmers in Europe, the Soviet Union, and elsewhere. Nevertheless, over a billion people in developing countries did not have the financial resources to purchase food and were thus largely excluded from the global marketplace that allocates this cornucopia.

On the whole, the developing world improved its per capita calorie intake slightly (and unevenly) while the developed world seemed to be reaching an upper limit; the United States even crossed an historical watershed by slightly decreasing its per capita meat consumption. Hidden in the production numbers were troubling patterns that could portend critical resource problems, including soil erosion, deforestation, desertification, salinization, and loss of soil nutrients. And by almost every measure, much of Africa was on a collision course with food and ecological disaster.

During 1985, virtually every government intervened to some degree in the farm and food sector, but no set of policies seemed able to untie the Gordian knot that world agriculture had become. After less than a decade of fairly modest government involvement in agriculture, U.S. policymakers found themselves committed to production control programs of record scope and cost. At the same time, ironically, some of the controlled market economies, like Hungary and China, were experimenting with market-like incentive programs.

The scientific breakthroughs that constituted the "green revolution" of the 1960s were yielding remarkable results in Asia but were proving ill-suited to transfer elsewhere in the developing world. Meanwhile, problems of pest resistance, fertilizer price increases and water shortages were forcing researchers back to their laboratories—in some cases even back to the conceptual drawing boards—to seek agricultural methods suited to changing circumstances. Africa was in dire need of a green revolution of its own, but there was considerable debate as to whether the diverse growing conditions of the continent could respond to any single breakthrough as South Asia had responded to miracle rice in the previous decade.

And beneath all the policy deliberations, the scientific advances, the investment of resources, and the hard physical labor, the engine that relentlessly kept the pressure on agricultural resources was population growth, which in the mid-1980s was adding about 80 million more mouths to feed every year, 93 percent of them in developing countries (2).

CONDITIONS AND TRENDS

THE RESOURCE BASE

The Earth can certainly provide more than enough food and fiber to serve not only its present population but also the 6.1 billion people expected by the year 2000 (3). In fact, scientists theorize that under ideal conditions—high levels of fertilizer, pesticides, and water, improved seeds and crops, unhampered international trade, careful management of soil resources, etc.,—the planet could sustainably feed and clothe the 10 or 11 billion people projected by the year 2100, when the global population may stabilize.

But such paper calculations must be viewed in the context of the hundreds of millions currently on the brink of starvation. (See Table 4.1.) When some people are too poor to purchase food, there will be hunger no matter how much the global agricultural economy produces. (See Box 4.1.) And if some nations are too poor to purchase the necessary agricultural inputs—fertilizer, pesticides, irrigation, and scientific research—there will be regions of the world that cannot attain their potential agricultural productivity; mathematical calculations must always be tested against real world situations. (See Box 4.2.)

Of the world's 13.25 billion hectares of land, about 30 percent, or just over 4 billion hectares, is estimated to be cultivable, the rest being too cold, too dry, too steep, or otherwise unsuitable. Of the cultivable land, about half is actually being farmed; much of the rest is in pasture, meadowland, or forest (4).

The developing countries encompass just over half of the land currently under cultivation. (See Table 4.2.) These countries also hold three quarters of the world's population. Consequently, cropland per capita is much lower than in the developed countries. In North America, the ratio is about 1 hectare per person; in East Asia it is one seventh as much. In the aggregate, the developed countries have more than half a hectare per person; the developing countries under one third.

Expanding the Cropland Base

Though only half the potentially cultivable land is now being farmed, cropland conversion is not easy, and one cannot infer a doubling of world food production simply through the expansion of production onto new land. For a variety of reasons, expanding the cropland base is expected to produce only a small percentage of increased food production. Partly this is because the available land is in the wrong place—the areas with the greatest need have the least amount of available land. In 1975, 63 percent of the population of the Third World lived in countries rated "land scarce" or "extremely land scarce" (i.e., countries in which more than 70 percent of the potentially arable land is already being cultivated). In contrast, only 15 percent of the developing countries' population lived in countries with abundant land resources (5).

In addition, most unused cultivable land has one or more serious problems that significantly decrease its potential. In central Africa, for example, the dense tropical rainforest, coupled with a lack of roads and other infrastructure, is a major hurdle, compounded by a host of serious diseases that plague humans, livestock, and plants. For example, the tsetse fly, whose bite can give both humans and animals incurable trypanosomiasis (sleeping sickness) dominates a region of 10 million square kilometers, an area larger than the United States (6). In the Andean region of South America the terrain is so steep that the thin soil erodes as fast as the forests are cut. In Brazil, 50 million hectares on the Cerrado plateau are so acid that they cannot be farmed without the addition of large amounts of lime and phosphate (7). Large areas in Africa are too dry to cultivate yearly and must be left fallow as many as five of every six years.

For such reasons, the world's land area in agricultural use is expanding at the rate of only one tenth of one percent per year (8), or about 50 million hectares per decade—and even that rate is expected to slow down. As Table 4.2 shows, cropland is projected to increase slightly faster, but by only 4 percent between 1975 and 2000.

Table 4.1 Prevalence of Energy Deficient Diets in 87 Developing Countries, 1980

	Insufficient Calories for an Active Working Life (Below 90 percent of FAO/WHO Requirements)				Insufficient Calories to Prevent Stunted Growth and Serious Health Risks (Below 80 Percent of FAO/WHO Requirements)			
Region[a]	Population in 1980 (millions)	Percent Change Since 1970	Share of Population in 1980 (percent)	Percent Change In Share Since 1970	Population in 1980 (million)	Percent Change Since 1970	Share of Population in 1980 (percent)	Percent Change in Share Since 1970
All Developing Countries (87)[b]	730	10	34	-6	340	14	16	-2
Low-income (30)[c]	590	41	51	4	270	54	23	3
Middle-income (57)	140	-43	14	-18	70	-44	7	-9
Sub-Saharan Africa (37)	150	30	44	1	90	49	25	4
East Asia and Pacific (8)	40	-57	14	-27	20	-57	7	-14
South Asia (7)	470	38	50	3	200	47	21	2
Latin America and Caribbean (24)	50	-15	13	-7	20	-21	6	-4
Middle East and North Africa (11)	20	-62	10	-25	10	-68	4	-14

Notes:
a. In 1980, these 87 countries had 92 percent of the population in all developing countries, excluding China.
b. The number of countries in the sample is indicated in parentheses.
c. In 1983, the per capita income of low-income countries was $400.
Source: The World Bank, *Ensuring Food Security in the Developing World: Issues and Options* (The World Bank, Washington, DC, 1985), pp. 2-6–2-9.

Box 4.1 Food Demand vs. Food Need

To the casual reader of nutrition literature, the phrases "real food demand" and "effective food demand" might appear interchangeable. But there is a world of difference between the two concepts. "Real food demand" is exactly what it sounds like: the need for food by hungry people. "Effective food demand" has a different definition: the amount of food that people can pay for.

Between the two definitions is a chasm wide enough for half a billion people to fall through. Each definition has its purpose: impoverished hungry people need to meet real food demand, while farmers (including impoverished farmers in developing nations) benefit from meeting effective food demand.

Effective food demand in middle-income, food-short nations like Saudi Arabia, Singapore, and Libya can be met through food purchases and imports. Real food demand in the impoverished hungry nations like Ethiopia, Mali, Mauritania, and Chad can be met only through direct food aid—gifts of food by the developed world.

The rate at which conversion does occur is uneven, with Latin America and East Asia showing higher rates of forest clearing for agriculture and permanent pasture. Conversely, Europe and the centrally planned nations of Asia are returning some cropland to other uses.

In some areas even the relatively small amount of cropland conversion that is taking place is having a significant deleterious effect. Clearing of moist tropical forests, in particular, generally has a severe and immediate impact, resulting in high levels of soil erosion, flooding, and nutrient loss. (See Chapter 5, "Forests and Rangelands," Focus on: Tropical Deforestation.) Since many tropical soils do not retain nutrients well, nations such as Brazil, the Philippines, and Indonesia have seen the rapid conversion of their lands from dense jungle to virtually barren wastelands; nutrients that had previously been recycled through the living biomass have been washed away by the first few years' rains following the forest clearing. In Southeast Asia as many as 25 million acres of once-forested land now bear only tenacious and useless sawgrasses that provide neither food, fuel, nor forage (9).

Deforestation has an additional severe impact on agricultural productivity. As fuelwood becomes prohibitively expensive or impossible to find, rural people shift to the burning of animal manure and crop residues, thus removing valuable nutrients and organic matter that were formerly returned to the soil. An estimated 400 million tons of dung are burned annually in areas where fuelwood is scarce. This burning of a potential fertilizer is estimated to depress grain harvests by over 14 million tons, an amount greater than the food aid provided annually to developing countries (10).

Desertification is another major hindrance to agricultural production. Because of their soil type and climate, some arid and semi-arid regions are suitable only for rangeland or pasture. If such areas are pressed into service for permanent cultivation, they rapidly lose their fertility and are subject to denuding and erosion. According to the United Nations Desertification Map of the World, more than two of every five acres (40 percent) in non-desert Africa are at risk of desertification; Asia's at-risk proportion is 32 percent and South America's is 19 percent. (See Chapter 5, "Forests and Rangelands.")

Conversion of pasture, rangeland, and forest to crop use *will* play a role in future food production; in 90 key developing countries the U.N. Food and Agriculture Organization (FAO) projects that expanded crop area will be responsible for about one quarter of the growth in food output from 1975 to 2000 (11). However, the lion's share of projected growth will come from increasing the productivity of existing cropland.

INCREASING THE PRODUCTIVITY OF CROPLAND

Most of the growth in agricultural production over the past several decades has resulted from increased productivity of cropland. This increased productivity has required the use of a wide range of physical, biological, and chemical inputs, including irrigation, tractors, fertilizers, pesticides, the breeding of high-yield varieties, and the development of fast-growing cultivars that allow double- and even triple-cropping. This "high-input" agriculture will be the major means of increasing food production in the future as well.

High-input agriculture also has a number of serious drawbacks, however. For one thing, it is expensive and therefore often impossible to transfer to the areas where higher production is needed most. For another, it requires a high degree of expertise and farmer training. Perhaps most limiting in the long term, high-input agriculture can have significant environmental costs, including the salinization and waterlogging of soils, the spread of water-borne disease, and the poisoning of non-target species (including humans) by pesticides.

Through the 1970s, as the world's average annual production of grain increased by 2.6 percent a year, productivity gains per hectare accounted for two percentage points, or about 80 percent of the growth. Growth in productivity of oilseed improved slightly faster, at 2.1 percent a year (12). Such productivity improvements are not projected to continue at this rapid rate but are expected to grow, between 1982 and 1994, at 1.3, 1.5, and 1.7 percent, for oilseeds, cereals, and fibers, respectively (13). While the overall rate of growth in agricultural production for developing countries has been increasing—reaching 3.3 percent during 1977–82 (14)—the growth rate for the world as a whole has been declining (15). It is not clear whether this decline is because technological limits have been reached or if it is simply the result of increasingly saturated market conditions.

As with everything else in agriculture, cereal yields vary tremendously in different regions (see Table 4.3), raising the possibility of huge total increases if developing nations could reach the levels of developed countries. While a few nations are achieving yields of over 4,500 kilograms of cereals per hectare, many countries in

Box 4.2 Land, Food, and People

The concept of "carrying capacity"—the number of people that a given amount of land can support—has fascinated scientists, economists and philosophers for centuries. Ever since Thomas Malthus postulated in 1812 that linear increases in food production and geometric increases in population growth would inevitably lead to starvation, there has been debate about the Earth's carrying capacity.

Carrying capacity is still not adequately enough defined to serve as a policy tool, nor are the available data nearly comprehensive or accurate enough to calculate the number of people the planet could hypothetically support. In 1984, however, the U.N. Food and Agriculture Organization (FAO) published "Potential Population Supporting Capacities of Lands in the Developing World," the most sophisticated attempt yet to estimate the carrying capacities of 117 developing nations (1).

The first pillar of the study is a series of 1:5,000,000 scale soil maps of the world created over a 20-year period by FAO and the United Nations Education, Scientific and Cultural Organization (UNESCO). The maps classify soils, terrain, and bedrock for the entire world by translating national mapping systems into an international framework.

The second pillar is the climate information from FAO's Agroecological Zone Project, which mapped crucial climate data for the world, including rainfall, radiation, temperature, and length of growing period. Superimposing the two maps produced a mosaic of thousands of units—or cells—with distinctive land and climate characteristics.

The researchers then used a complex computer program to determine the particular food crop that would provide the greatest amount of protein and calories for each land/climate unit, thus yielding a rough estimate of the maximum food-producing (calorie-producing) capability of each nation. The theoretical carrying capacity of each country was then calculated by dividing each nation's total potential calorie production by the FAO's minimum daily calorie requirement.

Because agricultural output depends so heavily on technological inputs, three scenarios were defined to fine-tune the results. The low level of optimization assumed that no fertilizer, biocides, or improved crop varieties were used, that no land conservation measures were practiced, and that traditional crop-mix patterns would be followed. The high level of optimization assumed full use of biocides, fertilizer, and conservation measures and the optimum crop variety throughout the entire cell. The intermediate level assumed basic use of biocides and fertilizer, simple land conservation practices, some improved crop varieties, and the optimum crop on half the land of each cell.

The results were expressed as a ratio by comparing the theoretical population that can be adequately fed first to the actual population in 1975, and then to the projected population in 2000. (See Table 1.)

For the 117 countries taken as a whole, the study revealed that the land base could provide food for twice the actual 1975 aggregate population, assuming the low level of farming inputs. As the level of inputs increased, the carrying capacity rose dramatically. On the other hand, projections for the year 2000 showed a significantly tighter situation at all input levels because of the large growth in population.

Overall, the developing world appears to be in tolerably good shape, able to support twice its 1975 poulation even at low input levels. On a country-by-country basis, however, the numbers are disturbing. At the 1975 low input level, fully 55 countries were "critical" (i.e., they had a ratio of less than 1:1 and were not able to support even their existing population). By 2000, 64 countries are projected to be critical, including the entire region of southwest Asia.

In fact, the model is overly optimistic. The study assumed that all potentially cultivable land is used to grow nothing but staple food crops or to provide pasture for livestock, and that the produce is divided equally among social groups to provide a basic calorie requirement. In reality, land would need to be set aside for forestry, vegetables, fibers, non-food cash crops and other uses (although the model did account for land lost to roads, cities, mining, factories, and parks), which would substantially reduce potential production. Moreover, the realistic per capita consumption would be considerably lower because of sharp inequities in distribution and other factors. Conversely, the study did not take into account the role of fish in the human diet, which would brighten the picture measurably, since 60 percent of the people in the developing world derive 40 percent or more of their protein from fish (2). Taking these variables into account, the authors suggest that all findings of the study should be reduced by about 30 percent to account for considerations too complex to model.

The single most unrealistic assumption of the study—and the one that cuts to the heart of the controversy over carrying capacity—is the artifical premise that there is no trade between countries. That assumption places Singapore and Saudi Arabia, for instance, in artificially bad shape, unable to feed their populations under any conceivable situation. In fact, of course, both are wealthy in resources other than productive land, and are able to trade resources or manufactured goods for food. Critics contend that any study of nation-by-nation carrying capacity is fatally flawed because land or climate is not necessarily a limiting factor: through the medium of money, all resources, including such non-physical items as knowledge and service, are theoretically exchangeable for food.

Nevertheless, the FAO study presents a compelling and sobering portrait of the agricultural capabilities of an increasingly populated developing world, many parts of which need to think in terms of self-sufficiency because they lack the financial resources to purchase food abroad.

References and Notes

1. U.N. Food and Agriculture Organization (FAO), *Potential Population Supporting Capacities of Lands in the Developing World*; a short summary of the study was published under the title *Land, Food and People* (FAO, Rome, 1984).
2. U.N. Food and Agricultural Organization (FAO), *The State of Food and Agriculture* (FAO, Rome, 1985), p. 63.

Table 1 Potential Population-Supporting Capacities Divided by 1975 and 2000 Populations

Input Level	Africa	SW Asia	South America	Central America	SE Asia	Average
1975 Ratios						
Low	3.0	0.8	5.9	1.6	1.1	2.0
Intermediate	11.6	1.3	23.9	4.2	3.0	6.9
High	33.9	2.0	57.2	11.5	5.1	16.6
2000 Ratios						
Low	1.6	0.7	3.5	1.4	1.3	1.6
Intermediate	5.8	0.9	13.3	2.6	2.3	4.2
High	16.5	1.2	31.5	6.0	3.3	9.3

Source: U.N. Food and Agriculture Organization (FAO), *Land, Food, and People* (FAO, Rome, 1984).

Africa are unable to attain even 1,000 kilograms per hectare. (See Table 4.4.)

In the developing world, the agricultural success stories of the past several decades are South and East Asia, particularly India and China. The principal beneficiaries of the green revolution, these regions used new crop varieties such as dwarf rice, semi-dwarf wheat, and opaque-two type maize to consistently propel production ahead of population gain. By the year 2000, the U.N. Food and Agriculture Organization (FAO) projects that per person calorie consumption in the Far East will have improved by almost 9 percent over 1974–76 levels (16). Nevertheless,

Table 4.2 Total and Per Capita Cropland and Resources, 1971–75 and 2000

Region	Cropland and Potential Cropland (million hectares)	Cropland[a] (million hectares) 1971–75	Cropland[a] (million hectares) 2000 (projected)	Cropland Per Capita (hectares) 1971–75	Cropland Per Capita (hectares) 2000 (projected)
Industrial Market Economies (Total)	1,023.3	400.3	399.1	0.55	0.46
United States	540.5	200.5	208.0	0.95	0.84
Western Europe	225.1	90.1	87.0	0.26	0.22
Japan	13.7	5.7	5.1	0.05	0.04
Other major exporters[b]	244.0	104.0	99.0	1.58	0.94
Centrally Planned Economies (Total)	884.4	414.5	420.0[c]	0.35	0.26
Eastern Europe	114.4	54.4	X	0.43	0.36
USSR	552.5	232.5	X	0.93	0.73
China	217.5	127.5	X	0.16	0.11
Less Developed Countries (Total)	2,232.0	662.0	723.5	0.35	0.19
Latin America	611.5	136.5	165.0	0.47	0.28
North Africa/Middle East	221.5	91.5	91.0	0.47	0.22
Other African LDCs	760.5	160.5	182.5	0.62	0.32
South Asia	437.5	207.5	207.0	0.26	0.13
Southeast Asia	99.9	34.9	41.0	0.35	0.20
East Asia	101.1	31.1	37.0	0.13	0.08
World (Total)	**4,139.7**	**1,476.8**	**1,538.6**	**0.39**	**0.25**

X = not available

Notes:

a. Cropland includes land under permanent and temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow or lying idle. This category is called "arable and permanent cropland" by FAO.

b. Canada, South Africa, Australia, and Argentina.

c. Cropland in centrally planned countries is thought to be near maximum. Growth in land used outside the agricultural sector approximately balances cropland area increase.

Sources:

1. U.S. Council on Environmental Quality, *The Global 2000 Report to the President*, p. 97 and p. 99.
2. U.S. Geological Survey (USGS), *Supporting Data for Environmental Trends* (USGS, Washington, D.C., 1983), p. 232.

with a massive population and widespread poverty, South and East Asia continue to be the least well-nourished parts of the world both in absolute numbers and in percentage of their populations. (See Table 4.1.) at present, well over 200 million Asians are seriously undernourished; by the year 2000, even though a larger percentage will be better fed, the number chronically short of calories is projected to reach 450 million (17).

Had it not been for the green revolution coupled with declining rates of population growth, the food situation in Asia would now be catastrophic.

Irrigation

The high-yielding plant varieties of the green revolution have certain specialized needs, including large quantities of water, fertilizer, and pesticides. Part of the Asian success story was the continent's ability to provide these inputs, particularly through irrigation.

Of the world's 212.9 million hectares of irrigated cropland in 1981, Asia (outside the Middle East) had 120.1 million hectares, or 56 percent (18). Use of irrigation spread rapidly throughout the world in the 1970s—2.3 percent per year—and by 1994 over a quarter of a billion hectares are projected to be free from dependence upon the vagaries of rainfall. (See Table 4.5.)

Table 4.3 Grain Yield Per Hectare, by Region, 1950–52 and 1980–82

Region	Average Yield (kilograms) 1950–52	Average Yield (kilograms) 1980–82	Change (percent)
North America	1,646	3,757	128
Western Europe	1,733	3,843	122
East Asia	1,419	2,973	109
Eastern Europe	931	1,819	95
South Asia	825	1,450	76
South America	1,217	1,854	52
Africa	757	1,044	38
Australia[a]	1,100	1,301	18
World	**1,186**	**2,247**	**89**

Note: a. Data are for 1981-83 to avoid trend distortion.

Sources:

1. U.S. Department of Agriculture (USDA), Economic Research Service, *World Indices of Agricultural and Food Production, 1974-83* (USDA, Washington, D.C., 1984).
2. U.S. Department of Agriculture (USDA), Economic Research Service, unpublished data.

Through a beneficial confluence of geography, hydrology, climate, financial investment, and managerial ability, India has become a showcase for the power of irrigation. In the period 1950–83, the nation's cereal production increased from about 55 million to 140 million tons per year, and over 50 percent of that increase is attributable to irrigation (19).

Table 4.4 Grain Yield in Selected Countries, 1974–76 and 1981–83

	Average Yield (kilograms/hectare/year) 1974–76	Average Yield (kilograms/hectare/year) 1981–83
Netherlands	4,771	6,357
Japan	5,620	5,278
Korea, Republic of	4,140	5,183
Germany, Federal Republic of	3,973	4,623
Egypt	3,921	4,254
United States	3,339	4,075
Korea, Democratic Republic of	3,590	4,010
German Democratic Republic	3,575	3,834
China	2,479	3,399
Indonesia	2,338	3,165
Canada	2,027	2,355
Argentina	1,971	2,353
Mexico	1,698	2,273
Bangladesh	1,771	1,993
Thailand	1,882	1,960
South Africa	1,403	1,608
Brazil	1,420	1,591
USSR	1,466	1,448
India	1,179	1,435
Australia	1,384	1,298
Ethiopia	966	1,280
Portugal	1,118	962
Nigeria	662	696
Sudan	645	603
Niger	395	408

Source: U.N. Food and Agriculture Organization (FAO), *Production Yearbook 1983*, Vol. 37 (FAO, Rome, 1984).

Table 4.5 Land Under Irrigation, 1970–94

	Million Hectares[a]			Average Annual Change (percent)	
Region	**1970**	**1981**	**1994**	**1970–81**	**1981–94**
North Africa/Middle East	16.0	18.3	20.6	1.2	0.9
Sub-Saharan Africa	3.4	4.5	5.2	2.7	1.1
European Economic Community	4.7	6.1	8.6	2.4	2.7
Other Western Europe	3.1	3.9	4.6	2.1	1.2
USSR	11.1	18.0	24.7	4.5	2.5
Eastern Europe	2.7	4.7	6.0	5.0	1.9
South Asia	45.0	56.8	69.9	2.1	1.6
East Asia	12.6	15.4	17.0	1.8	0.8
Asian Centrally Planned Economies	39.7	47.9	54.3	1.7	1.0
Oceania	1.6	1.8	1.9	1.2	0.5
Latin America	10.2	14.4	18.4	3.2	1.9
North America	16.4	21.1	26.3	2.3	1.7
World	**166.5**	**212.9**	**257.5**	**2.3**	**1.5**

Note: a. Estimates vary widely. Compare these figures with Chapter 8, "Freshwater," Table 8.6.
Source: Adapted from Winrock International, 1985, Reference 8.

Although irrigation is perhaps the single most effective way to increase yields of most crops (see Table 4.6), it has serious drawbacks—economic as well as environmental. Irrigation systems are very expensive to construct, with typical costs running $1,000–2,000 per hectare but ranging as high as $20,000 per hectare (20). They also require constant maintenance to prevent enormous rates of leakage, and close, sophisticated management. Overirrigation leading to waterlogged soil and excessive salinity is endemic. Since the Mesopotamians, history is replete with examples of agricultural systems that have failed because of faulty irrigation. Often the failure is permanent, leaving once productive farmland as wasteland. Salinization is currently a serious problem in both developed and developing countries, from the richest to the poorest. Worldwide, salinization alone may be causing as much land to be abandoned as is currently being brought under irrigation (21).

In India, where 40 million hectares were irrigated in 1982 (half of them by surface systems, half by wells) more than 7 million hectares were affected by salinity and alkalinity (22). Waterlogged areas are counted among those lands defined as "water-eroded," a staggering 73.6 million hectares out of India's total agricultural area of 143 million hectares. The total amount of land degraded by salinity and waterlogging is not precisely known but is estimated to be about half of the total land irrigated by surface systems (23).

Obviously, irrigation requires water. Egypt, Israel, and California may have been able to make relatively small areas of desert bloom, but the vast deserts of the developing world are essentially unirrigable.

Table 4.6 Extent of Irrigated Lands and Their Use for Food Production, in Selected Countries

Country	Percent of Cultivated Land Under Irrigation	Percent of Total Food Production From Irrigated Land
India	30	55
Pakistan	65	80
China	50	70
Indonesia	40	50
Chile	35	55
Peru	35	55
Mexico	30	X

X = not available
Source: W.R. Rangeley, 1985, Reference 19.

Unfortunately, the continent that needs the benefit of irrigation the most, Africa, has the lowest potential for it. Except in South Africa and along the Nile River, a variety of factors conspires against irrigation: its great expense, unfavorable topography and rainfall patterns, and insufficient numbers of trained managers. Also, the climate in much of the continent promotes the growth of disease carrying organisms, which flourish in the standing water of irrigation reservoirs and ditches. Only about 2 percent of Africa's arable land is now irrigated (24).

Fertilizer

After land and water, fertilizer is probably the most important factor in crop output; its increased use was responsible for about 55 percent of the increase in yields in developing countries between 1965 and 1976 (25). Fertilizer use correlates directly with output. By 1974–76, world fertilizer use had reached an aggregate level of 60 kilograms per hectare of arable land (ranging from a low of only 1 kilogram per hectare in several African countries to a high of over 700 in the Netherlands). (See Part IV, Chapter 5, "Food and Agriculture.")

Nations that use fertilizer heavily are not relying solely upon the natural materials at hand—crop residues, biomass, and animal waste. They are also producing or purchasing expensive synthetic petroleum-based fertilizer that is beyond the financial means of many developing nations. However, there are some low-cost strategies that even poor nations can adopt to increase their fertilizer supply. For instance, confinement of animals instead of wide-ranging grazing makes the collection of manure practicable. Also, the substitution of small biogas generators for the direct burning of manure—as the Chinese have done—provides energy for cooking and other uses while leaving a nutrient-rich slurry for crop enhancement.

Except for China, fertilizer use in the developing world remains much lower than in industralized countries, but it did increase during the 1970s. The developed countries at the beginning of that decade used 5.5 times more fertilizer per hectare than the low-income economies, but by 1980 that ratio had been reduced to 2.2:1 (26).

Pesticides

World pesticide sales grew from $8.1 billion in 1972 to $12.8 billion in 1983 (in 1983 dollars), with the most rapid growth occurring in the developing countries. The developed nations now use about 85 percent of all pesticides, down from 92 percent at the beginning of the decade (27). Pesticides are a vital element of the high-input, high-productivity agriculture that set new production records as it swept across Asia, parts of Latin America and other developing regions. However, as their use increases, pesticides' severe health and environmental impacts are becoming ever more evident.

Unfortunately, a significant fraction of the pesticides used in the Third World are those that have been banned for health and environmental reasons in some or all of the developed nations, DDT being the chief example. According to an estimate by the U.S. General Accounting Office, 29 percent of U.S. pesticide exports

Table 4.7 Deaths From Accidental Pesticide Poisoning, Selected Countries and Years

			Deaths	
Country	**Year**	**Cases**	**Number**	**Percent**
Cyprus	1972	15	2	13
Finland	1974	131	16	12
Ireland	1974	141	2	1
Israel	1974	53	X	X
W. Samoa	1972	10	X	X
Romania	1974	2,740	303	11
Syria	1971	1,064	167	16
Turkey	1974	1,680	156	9
United Kingdom	1973	98	14	14
Total		**5,932**	**660**	**11**

X = not available

Sources:

1. J.F. Copplestone. *Safe Use of Pesticides* (World Health Organization, Geneva, 1973).
2. J.E. Davies, "Health Effects of Global Pesticide Use," report prepared for the World Resources Institute (WRI) (WRI, Washington, D.C., 1985), pp. 4-5.

were not registered for use in the United States; of these, 20 percent had been canceled or suspended by the government as unsafe to health or the environment (28).

Despite more than three decades of experience in using pesticides, astonishingly little is known about their effects on human health. Reliable data on poisonings and deaths do not exist. The most comprehensive study, a 1973 effort by the World Health Organization (WHO), concluded that there are perhaps 490,000 cases of poisoning annually (with an uncertainty making the range 250,000 to 1,435,000) (29). The WHO committee estimated that the death rate from poisonings is 1 percent if antidotal facilities are available, but a cursory examination of selected country reports shows an actual death-to-poisoning ratio greater than one in ten. Though spotty, these findings demand concern. (See Table 4.7.)

From a purely environmental perspective, the accelerating rate at which insect, weed, and other pest species are becoming resistant to pesticides may be even more serious. Between 1970 and 1980, the number of arthropod species (insects, arachnids, and crustaceans) exhibiting reistance almost doubled, while for certain chemical groups such as the carbamates, the number of resistant species increased as much as 17-fold. (See Figure 4.1.) The total number of cases of arthropod resistance (the number of resistant species times the number of chemicals they are resistant to) now stands at more than 1,600 (30). Resistance has had major public health effects as well, as DDT-resistant mosquitoes have dashed hopes that malaria would soon be wiped out.

Areas that have suffered serious outbreaks of resistant pest epidemics include Indonesia, where 263,000 metric tons of rice were destroyed by brown planthoppers in 1975; northeastern Mexico, whose 280,000-hectare cotton industry has been wiped out since the 1960s by the boll weevil and the tobacco budworm; and Long Island in the northeastern United States, where farmers are spraying banned pesticides under special exemption up to ten times a season, polluting the groundwater in the process, and spending as much as $750 per hectare in a desperate attempt to control the Colorado potato beetle (31).

In response, the chemical industry and the world's agricultural research community have been gradually paying more attention to the concept of integrated pest management, a series of techniques that relies on smaller doses of more specifically targeted chemicals, the use of physical and biological controls, and sophisticated attention to the habits and life cycles of pests and their relationships to individual crops and agro-ecosystems. Although integrated pest management has been the subject of much discussion and research for well over a decade, its adoption has been slow, principally because it requires a high level of sophistication and cooperation on the part of farmers, extension agents, and pesticide sales personnel, and partly because in many cases it would mean a lower sales volume for chemical manufacturers (32).

Multiple Cropping

In parts of the developing world with extreme land scarcity, notably South and East Asia, high-input agriculture—including new varieties of fast-growing seeds—has enabled farmers to grow two and even three crops per year on the same parcel of land. In fact, because of the extreme intensity of land use, the Asian centrally planned countries have a harvested-land-to-arable-land ratio of 1.34:1—one and a third hectares of food are grown on every hectare of land each year. (See Table 4.8.)

No other region uses land as efficiently, although the trend toward double-cropping is increasing in other areas where the soil can handle such intensive use. However, multiple cropping is only suitable in limited areas because it depends upon the replenishment of nutrients through heavy use of fertilizer as well as careful management of irrigation to prevent soil salinization. In China, for example, the "grain first" policies of the 1960s and 1970s led to triple cropping in parts of eastern and southern China where it cannot be sustained (33). Moreover, the practice can increase a region's vulnerability to a season of unusually bad weather, a pest or disease outbreak, or other problems.

Summary

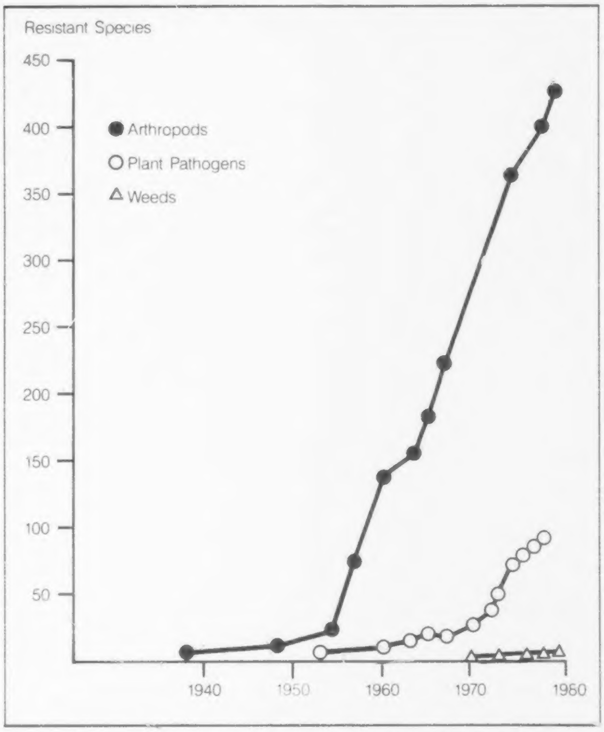
In conclusion, the vast proportion—about 88 percent—of the additional 400 million metric tons of grains that will be grown in the mid-1990s will be the result of improved productivity of current agricultural land, through the increased use of new irrigation, fertilizer, multiple cropping, and pesticides (34).

AGRICULTURAL PRODUCTION AND CONSUMPTION

Between 1974 and 1983 world food production increased at an annual rate of 2.2 percent, almost 0.5 percent faster than population growth. The developing countries significantly outperformed the developed countries, even taking into account faster population growth in the Third World, and by the end of the ten-year period the developing nations as a whole increased their per capita food production by about 10 percent.

However, as a whole the 36 "least developed" nations (35) did not share in the per capita agricultural improvement because of much higher birth rates. Their rate of food production increase, 2.1 percent per year, was fully half a percentage point less than their population growth

Figure 4.1 **Number of Species Resistant to Pesticides, 1940-80**



Source: G.P. Georghiou and R.B. Mellon, "Pesticide Resistance in Time and Space," in *Pest Resistance to Pesticides*, G.P. Georghiou and T. Saito, eds. (Plenum Press, New York, 1983), pp. 1-46.

(36). These nations are in worse shape now than they were in the early 1970s—which itself was a period of such concern about agriculture that the United Nations initiated the World Food Conference.

For the ten years following that Conference, FAO projected that food production would increase in the developing world by an average of 2.6 percent per year. Ten years later, only Africa had not reached that goal. The rest of the developing world was able to make substantial agricultural progress on a per capita basis because the general rate of population growth was significantly lower than had been projected in 1974. Africa combined a less-than-hoped-for production increase with a higher-than-predicted birth rate (37). (See Table 4.9.)

The world's production of cereals, including wheat, rice, and coarse grains (primarily maize) reached a world total of 1.78 billion metric tons in 1984, the greatest amount in history and a remarkable 8.5 percent increase over 1983. However, the developing world's increase was just 2.3 percent, sufficient only to keep a step ahead of population growth. Meanwhile, much of the huge harvest in the industrialized world was unmarketable and went into stockpiles; by the end of the 1984–85 season, global cereal carry-over stocks were projected to reach 294 million metric tons or 18 percent of expected world consumption (38).

Throughout the 1970s, the fastest growth in cereal production was in North America, Latin America, and the centrally planned nations of Asia. In North America, with decreasing growth of population and demand, the huge production is shifting the U.S. and Canadian agricultural economies ever more toward the export market.

One of the more remarkable developments of the 1970s was the strong growth in meat production and consumption. By 1983–84 just over 50 percent of the world's grain production went to feed animals, not people. Everywhere but Africa (where per capita consumption fell) and the high meat consumption countries like Argentina, Australia, New Zealand, the United States, and Canada (where market saturation is apparently being reached), meat consumption was up sharply.

Rising incomes almost always create a rising demand for meat. This has been particularly apparent in the Middle East, East Asia, and in the less wealthy countries of Europe. In the 1970s, per capita meat consumption grew by 1 percent a year above population growth, and global production increased almost 3 percent a year. This rate of growth is expected to decline somewhat in the coming less prosperous years, but will continue. Even South Asia, with its low income and traditionally vegetarian diet, will exhibit growth, although by 1994 it will only bring per capita yearly consumption up to three kilograms (39).

Another indicator of rising meat production was the sharp growth in oilseed (primarily soybean) production and consumption (40). Oilseed is the key ingredient in high-protein animal feeds, upon which livestock herds in North America, Western Europe, and elsewhere are increasingly dependent.

Finally, the world produced about 22 million metric tons of fibers annually in the early 1980s, most importantly cotton, jute, and wool. Fiber sales have suffered from competition with synthetics for several decades, and per capita fiber consumption declined in the 1970s. The decline is expected to continue in the future, though at a lesser rate (41).

WORLD FOOD TRADE

One of the most dramatic developments in agriculture has been the rapid rise in the volume of world trade since World War II, and particularly since the early 1970s. In the period 1950–72, while world agricultural production was increasing at an annual rate of 2.85 per-

Table 4.8 **Harvested Land as Percentage of Arable Land, 1970, 1981, and 1994**

	1970	1981	1994
North Africa/Middle East	58	58	59
Sub-Saharan Africa	73	75	75
European Economic Community	71	74	76
Other Western Europe	65	67	70
USSR	63	65	66
Eastern Europe	81	78	78
South Asia	95	97	96
East Asia	91	96	101
Asian Centrally Planned Economies	129	134	142
Oceania -	30	41	44
Latin America	69	70	70
North America	46	59	60
World	**72**	**76**	**78**

Source: Adapted from Winrock International, 1985. Reference 8, p. 30.

Table 4.9 Annual Percent Increase in Food Production and Population, 1974–84 and Extrapolation to 1985

	Food Production		Population	
	1974–84[a]	1985[b]	1974–85[a]	1985[b]
Developing Market Economies	3.0	2.6	2.5	2.7
Africa	1.9	2.5	3.1	2.9
Far East	3.6	2.4	2.3	2.6
Latin America	3.0	2.9	2.4	2.8
Near East	2.6	3.1	2.7	2.9
Asian Centrally Planned Economies	4.1	2.6	1.4	1.6
All Developing Countries	3.1	2.6	2.1	2.4

Notes:
a. Actual trend.
b. Extrapolations by the World Food Conference, 1974.
Source: United Nations, "The World Food Problem" *in U.N. World Food Conference* (FAO, Rome, November 1974).

cent, world agricultural trade was expanding by 4.95 percent. In the decade that followed (1972–81), trade burgeoned even faster, 6.25 percent a year, despite a drop in world production growth to 2.35 percent annually. (See Table 4.10.) If 1950 is taken as a base year, world agricultural trade volume had doubled by 1962, tripled by 1972, and quadrupled by 1980 (42). Moreover, the increased value of the exports was greater even than the increased volume (43).

About one of every ten kernels of grain crosses an international border between the time it is harvested and consumed. And for most kernels the trip involves crossing either the Atlantic or Pacific Ocean, for by the end of the 1970s fully 87 percent of grain exports originated in North America.

It is difficult to overstate the importance of North America, particularly the United States, in world grain trade. The United States is not literally "feeding the world," but it certainly provided the marginal increase in calories that improved the lot of millions of people in developing nations in the past decade. With the exception of North America (and, to a much smaller degree, Oceania and the European Economic Community), the world in the early 1980s was consuming annually almost 150 million metric tons of grain more than it was producing. In fact, these grain-deficit countries had increased their dependence on imports through the 1970s at the astonishing rate of 12.5 percent a year (44), although they were partially balancing that deficit through the export of many non-grain agricultural products.

In the coming decade the pattern is likely to continue, even if rates decline. By the year 2000, North America will be approaching the 200-million-metric-tons-per-year mark in exports. The European Economic Community will have become a substantial exporter, thanks to heavy production subsidies, but the output will be easily absorbed by the rest of Europe, which is grain short.

Why is world agricultural trade booming? What does it mean and where is it heading? The answers are complex, and future developments are difficult to predict.

Several coincidental events in the early 1970s combined to give world agricultural trade a boost. Among them were the liberalization of the foreign exchange regime with the end of fixed exchange rates, huge Indian and Soviet grain purchases in 1972, and the first major changes in U.S. stockholding policy since World War II. In addition, the psychological impact of the 1973 OPEC oil price increase led to a destabilization of grain markets as many nations made immediate purchases to avoid future price increases. Moreover, rising world affluence, particularly among the middle-income developing countries, placed many nations in the category of potential food buyers for the first time. (The Middle East, for example, converted much of its oil profits into grain-fed meat; meat imports in the region grew from under 100,000 metric tons in the early 1970s to over a million metric tons in the early 1980s.) Finally, credit was still being liberally extended in the 1970s and much of the growth in the global food trade was debt-financed. The tightening of credit in the early 1980s was partially responsible for the trade turndown from 1981–85.

The 1970s seem to have marked the passing of a psychological barrier to agricultural trade as well. The general presumption that nations should strive to be self-sufficient in food apparently began fading with the realization that other regions might be able to provide food, at least at the margin, more cheaply.

World trade maximizes production and consumption, and evens out regional peaks and valleys in production

Table 4.10 World Trade in Grains, Meat, Milk, and Oilseed, by Region

	Grains		Meat		Milk		Oilseed	
	One-Year Average, 1980-82 (million metric tons)	Average Annual Percent Change Over Previous Decade	One-Year Average, 1980-82 (million metric tons)	Average Annual Percent Change Over Previous Decade	One-Year Average, 1980-82 (million metric tons)	Average Annual Percent Change Over Previous Decade	One-Year Average, 1980-82 (million metric tons)	Average Annual Percent Change Over Previous Decade
North Africa/Middle East	-29.2	12.8	-1.18	26.0	-7.9	12.4	-1.7	-14.4
Sub-Saharan Africa	-5.8	11.4	-0.08	-8.1	-1.3	5.3	2.6	-3.5
European Economic Community	4.3	2.0	0.12	1.0	11.3	17.9	-31.1	5.6
Other Western Europe	-11.0	8.5	-0.03	-14.8	1.0	3.8	-5.6	5.7
USSR	-36.5	-22.7	-0.80	23.9	-4.3	-14.5	-2.7	-23.3
Eastern Europe	-11.4	5.5	0.49	13.9	0.3	5.0	-6.4	8.0
South Asia	-1.6	-11.1	0.05	33.2	-0.6	19.1	2.9	1.8
East Asia	-28.8	4.9	-0.82	8.5	-1.9	3.9	-8.1	4.7
Asian Centrally Planned Economies	-18.6	12.1	0.23	3.4	-0.1	6.6	-1.2	44.1
Oceania	15.6	5.6	1.47	2.5	5.6	-2.3	0.0	31.1
Latin America	-7.6	-10.9	0.56	-2.5	-2.2	4.0	16.0	10.8
North America	132.8	9.3	0.18	3.8	-1.1	24.6	37.0	6.8
World Total[b]	**152.7**	**7.8**	**3.10**	**3.2**	**18.2**	**6.5**	**58.5**	**6.2**

Notes:
a. Negative amounts are imports. Positive amounts are exports.
b. Exports only.
Source: Adapted from Winrock International, 1985, Reference 8, pp. 43, 44, 47, and 48.

and prices. Thanks in part to booming international trade, world production has kept up with effective demand despite falling prices for grain and most other food products in 25 of the last 30 years. In all, real agricultural prices were 25 percent lower in 1980 than in 1950 (45).

Conversely, trade barriers tend to decrease prices for exporting producers, increase prices for consumers in importing countries, and lead to unnecessary shortages and surpluses. However, the internal pressure to protect various industries, crops, and economic groups is often intense, and virtually every government has erected one trade barrier or another. When food supplies are relatively tight, trade barriers are only a minor problem, but favorable weather years with large harvests and abundant supplies can trigger major trade disputes.

In the mid-1980s, because of huge harvests in Europe, the United States and the Common Market found themselves on the verge of a trade war. Low prices and high debts forced many American farmers into bankruptcy. At the same time, thanks to price supports given the politically powerful dairy industry, the United States found itself with enough surplus to give every American a two-month supply of butter, a three-month supply of cheese, and a two-month supply of milk (46), even though the price of dried milk was at its all-time high. Meanwhile, in Europe, agricultural subsidies were accounting for 79 percent of the entire budget of the European Economic Community (47).

As world trade burgeons, the traditional nation-based structure of agriculture is giving way. Suddenly, good weather in Europe can put an American farmer out of business, while a U.S. political decision on wetland protection requirements can raise the price of meat in Korea. Moreover, the traditional market forces of supply and demand are beginning to take a back seat to financial variables that have nothing to do with agriculture: currency exchange rates, debt-driven interest and government economic subsidies. Farmers are finding themselves worrying more about the rise of mortgage rates and the fall of currency prices than the rising of the sun and the falling of the rain.

Currency exchange rates have such a severe impact on agricultural prices that large chunks of the market are going underground and avoiding cash transactions entirely. Barter and its more complex variant, countertrade (three-, four-, and multi-way barter), have grown from marginal amounts (mostly within the Soviet Union and Eastern European countries) to more than 30 percent of all world food trade. Although they are practical solutions to a serious problem, barter and other forms of non-market transactions (like bilateral long-term contracts) are leading to greater government involvement in world food trade and less reliance on market mechanisms to make decisions and allocate resources.

FOOD AID

When a nation can neither grow nor afford to import enough food for its citizens, it must appeal to the generosity of the better-off members of the world community. In 1974, the participants at the World Food Conference set a minimum target of providing 10 million metric tons of food aid annually to needy nations. However, the donor nations did not reach this goal until ten years later, when 10.4 million metric tons were made available in 1984, largely because of the catastrophic famine in Africa. But by then the amount was only a fraction of the real need. The FAO estimated that 111 countries required 20 million metric tons of food aid in 1985; the U.S. Department of Agriculture calculated that, based on nutritional needs, 67 low-income countries required 25.8 million metric tons (48). For the longer term, assuming an end to African drought, the United Nations World Food Program estimates an annual worldwide food aid need of approximately 14 to 15.5 million metric tons.

The largest food donors are the United States, the European Economic Community, Canada, Japan, and Australia. Fifty countries contribute either food or funds, including even India, China, Egypt, Mauritius, and Togo. The largest recipient countries in 1982–83 were Egypt, Bangladesh, Sri Lanka, Pakistan, and Ethiopia.

Food aid is controversial. Emergency food shipments to regions facing short-term famine are universally supported, as shown by the unprecedented outpouring of aid to Africa in 1985. (See "Recent Developments," below.) There is vigorous debate, however, about the efficacy of long-term food aid. Free or low-cost food can become incorporated into the general food economy of recipient countries, driving down the price of food and undermining the already-precarious financial position of poor farmers. With no incentive to grow food to sell, farmers remain unproductive and food aid becomes indispensable.

Critics also point to the extent to which food aid is a pawn in global power politics, with "friendly" or strategically sensitive developing countries receiving more aid and "unfriendly" or less politically important countries receiving less, regardless of need. Others see food aid as a disguised means of disposing of surpluses. Moreover, the donated food does not always make its way to those who truly need it; reports of corruption and malfeasance are common. The rural poor of many developing countries—who are predominantly women and children—are at particular risk because of their remoteness from food distribution centers and their lack of political power.

Nevertheless, food aid is strongly backed by politically powerful producers in the food-surplus nations and has become an accepted institution that currently comprises about five percent of total world food trade (and, in fact, is becoming difficult to distinguish from other components of that trade). While food aid may not be an appropriate long-term solution, the vast amount of hunger in the world, coupled with falling per capita agricultural production in many low-income developing countries, and rising foreign debts, guarantees that food aid will remain a substantial element of the world agricultural economy for a long time to come.

FOCUS ON: EROSION

Soil erosion is as old as the planet. It causes major losses in agricultural and forest productivity; yet over time it has also been responsible for the productivity of such fertile areas as the Nile, Indus, Ganges, and Mississippi River valleys. Under normal agricultural conditions, the average erosion rate is estimated to be about 0.5 to 2.0 metric tons per hectare per year (49). Put another way, approximately one vertical centimeter of topsoil would be washed or blown away every 80 to 280 years, depending upon numerous related factors such as soil type, slope, and the nature and intensity of wind and rainfall. This rate is also the immutable pace at which new soil is created by nature.

However, as croplands become overworked and mismanaged, erosion often rises dramatically. Hard numbers are impossible to come by, for erosion is a notoriously site-specific phenomenon. The world's rivers are believed to deliver about 24 billion tons of sediment to the oceans each year (50). In addition, many billions of tons of eroded soil never make it to the sea; they either settle along stream bottoms or silt reservoirs behind the world's dams. One single dam, the Sanmer on China's Huang (Yellow) River, traps 400 million metric tons of sediment a year (51). Many more billions of tons are eroded by the wind; scientists in Hawaii can tell when spring plowing begins in China because they see the dust over the Pacific (52), and up to an estimated 400 million tons of North African sand are blown westward into the Atlantic every year (53).

That erosion is affected by both slope and human activities is readily apparent by studying the sediment load of some of the Earth's major waterways. India's Ganges River, which drains just over 1 million square kilometers of intensively worked farmland and heavily harvested forestland in India, Bangladesh, Nepal, and Tibet, delivers 1.46 billion metric tons of sediment to the Bay of Bengal every year. In contrast, the Amazon River, which drains a much larger area of relatively unspoiled tropical forest covering nearly 5.8 million square kilometers, carries only 363 million metric tons of sediment per year. On a drainage area basis, the riverborne erosion rate in the densely populated plains and mountains of northeastern India is more than 20 times higher than in the sparsely populated jungle of Brazil. (See Table 4.11.)

China's Huang River is the most sediment-laden river on earth. From just 668,000 square kilometers of drainage—much of it through the heavily eroded Loess Plateau south and west of Beijing—the river dumps 1.6 billion metric tons of soil into the East China Sea. In its middle reaches, the river carries about 700 kilograms of silt per cubic meter of water, or about 50 percent silt by weight, just under the level classified as liquid mud. As this silt has settled out over the centuries, the height of the river bottom has risen, forcing the construction of ever-higher dikes along the riverbanks. Today, as it approaches its mouth, the Huang River flows in a channel raised three to ten meters above the surrounding countryside (54).

Erosion is widely reported, though not most painfully felt at the country and regional level. In Guatemala, 40 percent of the productive capacity of the land has been lost because of erosion, and several areas of the country have been abandoned because agriculture has become uneconomic. In Turkey, planners estimate that 75 percent of the land is affected, with 54 percent severely or very severely eroded. In Haiti, which loses 14 million cubic meters of topsoil a year, there is no top quality soil left. Cleared areas of Nepal lose between 35 and 75 metric tons of soil per hectare per year, leading one observer to suggest that the country's most precious export is its soil (55). In India 13 million hectares are eroded by wind and nearly 74 million by water, an astonishing one-quarter of India's total land area (56). Since 1957 alone, China has lost about 11 percent of its arable land to erosion, desertification, and conversion to nonagricultural uses (57).

Many factors cause erosion, but the two most important are degree of slope and the amount of bare soil exposed to the elements. Research in Nigeria, for instance, revealed that land with a 1 percent slope, planted in cassava, suffered erosion of a modest three metric tons per hectare per year. On a 5 percent slope, however, erosion jumped to 87 tons, and on a 15 percent slope soil eroded at a disastrous 221 tons per hectare per year. At that rate, all the topsoil from the test plot would disappear in a decade (58).

Soil is left bare for many reasons. Often fields are left barren between harvest and planting time. After forest is cleared there is a period of exposure before crops are planted and germinate. And, of course, the soil between row crops is bare if it is not mulched.

A shift in cropping patterns in the U.S. state of Missouri in the 1930s provided dramatic evidence of the effect of row cropping on erosion. When land was in corn/wheat/clover rotation, with the clover providing a grass-like mat over the soil, erosion took place at the rate of 6.75 metric tons per hectare. When the land was converted to corn-only agriculture, erosion jumped to almost 49.2 metric tons per hectare, a seven-fold increase (59). The clover mat not only held the soil on its third of the fields but also apparently trapped airborne and waterborne soil particles from the other two thirds. However, most large

Table 4.11 Estimated Annual Soil Erosion, Selected River Basins

River	Outflow	Area of Drainage Basin (thousand square km)	Average Annual Suspended Load (million metric tons)	Estimated Annual Soil Erosion From Field (metric tons per hectare)
Niger	Gulf of Guinea	1,114	5	0
Congo	Atlantic Ocean	4,014	65	3
Nile	Mediterranean Sea	2,978	111	8
Amazon	Atlantic Ocean	5,776	363	13
Mekong	South China Sea	795	170	43
Irrawady	Bay of Bengal	430	299	139
Ganges	Bay of Bengal	1,076	1,455	270
Huang (Yellow)	Yellow Sea	668	1,600	479

Source: El-Swaify et al., Soil Erosion and Conservation in the Tropics, American Society of Agronomy (Madison, Wisconsin, 1982), p. 8

farms in the United States have abandoned crop rotation because of the size and needs of giant farm machinery, and are substituting chemical fertilizer for declining inherent soil fertility.

Erosion damages and depletes the soil in complex, subtle ways. Most seriously, it reduces the water-holding capacity of soil by selectively removing organic matter and the finer particles; soils that have been seriously degraded by erosion can lose up to 93 percent of their water infiltration capacity (60). Erosion also removes soil nutrients such as phosphorous, potassium, nitrogen, and calcium, as well as soil organic matter; the nutrients can be replaced with synthetic inorganic fertilizer or with crops of nitrogen-fixing legumes. The organic matter must be restored by adding biomass from crop residue, mulch, etc. Finally, erosion can stunt plant growth by restricting the depth of soil available for vigorous root growth.

Erosion has two major kinds of effects: on- and off-site. On the eroding field itself, the loss of topsoil reduces the long-term productivity of the land. Numerous studies in the United States reveal a decline in corn yields of three to six bushels per acre for each inch of topsoil lost. For wheat the reductions are between 0.5 and 2.5 bushels per acre. On average, these diminished yields represent losses of 6 percent per inch of eroded topsoil for both crops (61).

In experiments where the entire topsoil was scraped off experimental plots, the results were—not surprisingly—far more dramatic. In Mexico, land deprived of 18 centimeters of topsoil grew only 0.6 metric tons of corn per hectare compared to 3.8 tons in the control field. In Nigeria, when 15 centimeters of topsoil were scraped off, corn yields plummeted from 6.5 metric tons per hectare to only one ton (62).

Off-site effects are also severe, not so much to food production as to the world's waterways. In the United States, which has carried out the most extensive investigations of erosion rates and effects, about 3 billion metric tons of sediment are washed into waterways each year (not counting Alaska and Hawaii), with off-site damages estimated at $6.1 billion. This damage includes a decline in fish populations, the loss of recreation potential, destruction of coral reefs, a decrease in the amount of water stored in reservoirs, the loss of hydropower potential, and the cost of dredging rivers and harbors for navigation (63).

In the Third World the decline in hydroelectric capacity due to sedimentation behind dams is particularly costly, since for many developing countries these expensive public works projects are expected to provide a basis for future economic growth. Pakistan's Mangla Reservoir is a case in point. Built with a 100-year life expectancy, it will fill up with silt at least 25 years and possibly even 50 years ahead of its time. In Colombia, because of heavy erosion in the upper watersheds, the Anchicaya Dam had lost 25 percent of its storage capacity only two years after it was completed (64).

Soil erosion has been called a "quiet crisis" and a "creeping catastrophe" because it is generally not visible to the farmer or the policy-maker until after much of the damage has been done. Moreover, it is difficult to convince wealthy landowners—much less impoverished subsistence farmers—to budget time and money for erosion control techniques whose payback period may be measured in years or even generations. In addition, in areas where the off-site effects of erosion are more damaging than the on-site effects, it may be unreasonable to expect farmers to expend resources to protect lands hundreds or thousands of kilometers downstream.

There is no single solution to erosion. Appropriate measures depend on site characteristics, and most control measures work best when taken together. On denuded hillsides, reforestation is needed both for controlling erosion and for providing fuelwood. In many areas, particularly in Africa, agroforestry—the interplanting of crops and trees, particularly nitrogen-fixing trees such as *leucena*—has been effective in restoring soil fertility and preventing erosion. Even without shifting to full-scale agroforestry, shelter belts of trees planted near cropland can help reduce wind erosion.

Terracing is the ancient and traditional method of reducing erosion, particularly in Asia. In early days, when population growth was gradual, there was time to build strong and well-designed terraces that have lasted for centuries. Today, particularly in Latin America, population pressure has forced people higher and higher onto extremely steep mountain slopes, and there is often no time to construct proper terraces. Poorly built terraces are a major contributor not only to soil erosion but also to death and destruction from the mudslides that have become so feared in the Andes.

Erosion on hillsides can also be caused by grazing animals, whose heavy steps break up the soil. Stall feeding of livestock can contribute to erosion control in such areas. (This method also allows the collection and use of manure.) Preventing overgrazing on steep slopes in drought-prone areas is also critical to maintaining the protection provided by vegetative cover.

Erosion is intimately tied to fuelwood shortages. Recycling of crop residues is essential for soil maintenance and protection against erosion. But when fuelwood is short, residues are diverted for use as fuel. In China, which suffers from acute energy shortages in its rural areas, as much as 75 percent of available residues are used for fuel; in the United States 70 percent are recycled (65).

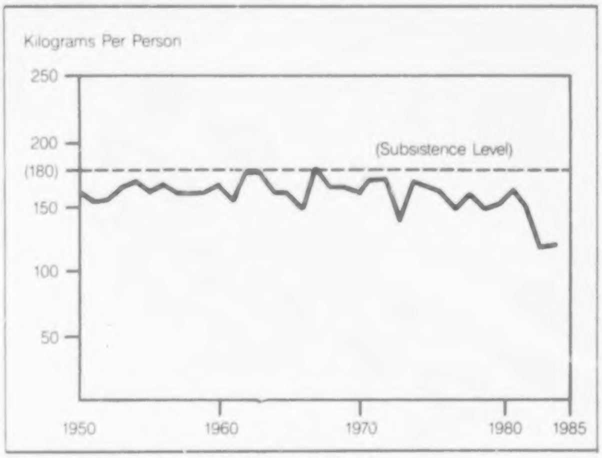
The recently developed method of "no-till farming," in which crop residues are left as mulch on top of the field and small holes are punched through the mulch to plant the seeds, is a strikingly successful erosion-control strategy. However, the method may prove to have serious drawbacks, because it requires heavy use of herbicides to suppress the weed growth that tilling normally eliminates. The impacts of herbicide use on soil and water quality and on the development of resistance in weed species are not yet well explored. No-till and minimum-till agriculture (where narrow rows are tilled but the spaces in between are left unplowed) has spread very rapidly in the United States, expanding from 10 percent of harvested cropland in 1972 to an estimated 32.6 percent in 1984 (66). However, no-till agriculture is not widely used in other parts of the world.

Finally, data collection to fill the gaping holes in current knowledge of erosion rates, and education of farmers and policy-makers, are top priorities. Available statistics do not yet allow reliable projections of future erosion rates and impacts. We do know enough about the global agricultural situation, however, to realize that whatever erosion-control steps can be economically taken should be taken.

AGRICULTURE IN AFRICA

While most of the developing world has been making slow but steady progress in either increasing its agricultural production or improving its economic ability to purchase food, Africa has been losing ground in the effort to feed itself. (See Figure 4.2.)

Figure 4.2 Per Capita Grain Production in Africa, 1950–84



Source: Brown and Wolf, 1985, Reference 67, p. 9.

Virtually the entire continent, but particularly a huge arc of countries extending across the Sahel from Mauritania to Ethiopia and then south to Mozambique (see Figure 4.3), is caught in a dangerous cycle of rapid population growth, inability to afford technological advances in farming, expansion of agriculture onto marginal and sensitive lands, severe deforestation and erosion, declining agricultural productivity, and, too often, misguided agricultural policies combined with unaccountable state marketing institutions. Coupled with 17 years of below-average rainfall in most of the continent (67) plus three years of drought (see Chapter 8, "Freshwater," Box 8.1), these conditions have led to the starvation deaths of over a million people (68) and to the physical and psychological ravaging of uncounted millions more.

One of the major causes of Africa's food and development problems is the continent's population growth rate, which in the decade 1974–84 stood at 3.1 percent a year (69) and burdened farmers with about 1 million more mouths to feed every three weeks. At that rate Africa would have 1.5 billion people—three times its current population—to feed by the year 2025. Some of the demographic trends defy the imagination: current projections suggest that the population of Ethiopia will not level off until it reaches 181 million; and Nigeria's growth curve points to a hypothetical stationary size of 532 million inhabitants—about the current population of the entire continent (70).

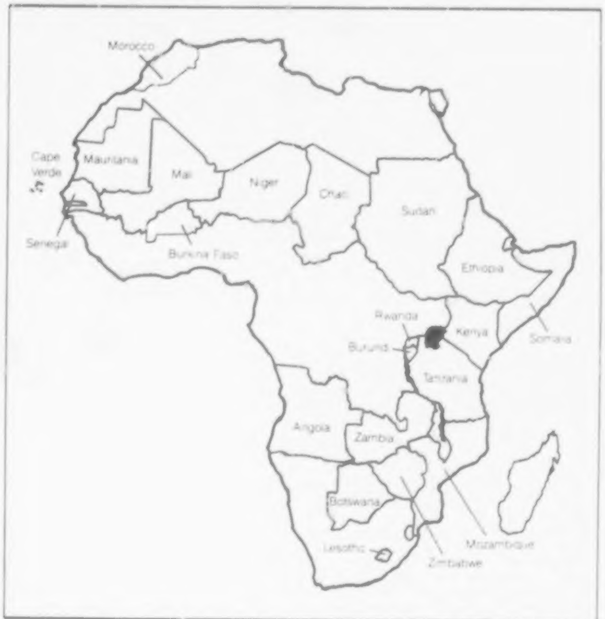
Meanwhile, although it is the second largest continent, Africa is not particularly well suited to agriculture. Over 80 percent of its soils have fertility limitations, and the climate in 47 percent of the continent is too dry for rain-fed agriculture (71).

In earlier days, with less population pressure, Africans developed an indigenous agricultural regimen that suited the continent's unique ecology and served the people well, though at the subsistence level. Called "shifting agriculture" or the "bush fallow method," this system involved semi-nomadic cultivation, which allowed fields to recover nutrients and moisture for several years after a season or two of crop production. But increased population density and the advice of agricultural advisors from developed countries are leading Africans to abandon this type of farming in favor of methods that have proven successful in the more fertile and wetter parts of the world. Even if this shift in farming methods makes sense for the continent (which is far from certain), Africa does not now have the technological infrastructure to support such a change: irrigation systems are inadequate or nonexistent, fertilizer availability and use are far too low to replenish nutrients on intensively cropped lands, and there is insufficient capacity to handle the pest problems associated with repeat farming of plots. Moreover, there has been little cultural orientation toward soil conservation techniques, such as the terracing found in East Asia, because previous population densities generally did not warrant it.

Coupled with Africa's agricultural problems is the continent's acute energy shortage. Fuelwood is Africa's primary fuel, even in oil-exporting Nigeria. Both closed-canopy and open-canopy forests are being cut down at a high rate, with devastating effects on the soil. Not only are trees no longer there to cut the wind, anchor the soil, and reduce the erosive power of falling raindrops, but as fuelwood becomes scarce, people begin to switch to dried dung and other types of biomass that formerly returned nutrients to the soil.

The policies of most African nations must share the blame for the dismal state of the continent's agriculture. Most African governments have not invested enough money in agriculture. Between 1978 and 1982, while government spending per farmer increased in Latin America, the Near East, and the Far East, it declined by 0.1 percent a year in Africa, according to an FAO study (72). Similarly, African farmers do not receive high enough prices for what they produce to make it worthwhile to undertake the risks necessary for higher production or to invest in land conservation techniques. Many nations opt for low food prices to satisfy their urban poor rather than for higher producer prices to stimulate the farm sector. Some, such as Egypt, have also incorporated food aid shipments into their economies in a way that permanently undercuts their own farmers' ability to sell food. As one bitter relief worker in the Sahel put it, "Starve the city dwellers and they riot; starve the peasants and

Figure 4.3 Twenty-one African Countries Affected by Abnormal Food Shortages, December 1984



Source: U.N. Food and Agriculture Organization (FAO), 1985. Reference 48, p. 21.

they die. If you were a politician, which would you choose?" (73).

Finally, Africa (along with the rest of the developing world) was partly a victim of what now appears to have been bad advice from foreign development officials. Postwar development theory generally held that Third World countries could move directly from subsistence farming to industrialized economies, including "industrial agriculture"—cash-cropping of such commodities as coffee, cotton, pineapples, tea, and nuts—without establishing a strong, broad-based indigenous agriculture. In Africa particularly, resources were optimistically shifted to manufacturing while key infrastructure improvements in rural areas, such as roads connecting fields to markets and storage facilities, were put off. The net result is that not only has industrialization failed (for a variety of complex reasons), but agriculture also has been hurt, and food crops have fared worse than commercial crops.

With five exceptions (Cameroon, Central African Republic, the Ivory Coast, Rwanda, and Sudan), population growth has outstripped production in all 41 sub-Saharan countries. Per capita food production has dropped by a staggering 20 percent over the past decade in such countries as Angola, Ghana, Mozambique, Senegal, and Somalia. Even before the current drought, 25 percent of the population of the sub-Saharan nations had become dependent on imports for their food. Not since 1970 has the continent produced as much food as it consumed (74). Indeed, for the past 20 years, African commercial food imports have risen 9 percent a year (75).

Helping Africa rescue itself from further agony will be a long, difficult process. It will require new agricultural systems and technologies designed for Africa's soils and climates, and appropriate to its cultural, educational and financial conditions. Strategies to integrate agriculture, forestry, energy, and rural development will be vital. Massive amounts of tree planting, terracing, contour plowing and other soil conserving technologies will be necessary, as will new drought- and pest-resistant crop varieties. Traditional technologies, such as simple water harvesting and water conservation techniques, must be adapted to present conditions. Ways must be found to lessen the pressure on fuelwood resources. (See Chapter 7, "Energy," Focus on: Fuelwood Scarcity.) Strategies that allow the successful co-existence of pastoralist and settled agriculture in arid conditions must be developed. (See Chapter 5, "Forests and Rangelands," Primary Production in the Sahel, Box 5.1.)

Perhaps most important, African governments must reevaluate their agricultural policies to provide greater economic stimulus on the production side. Stimuli could include shifting the development focus from urban to rural areas; improving the quality and increasing the amount of agricultural research; allowing freer pricing policies for locally grown food; reorganizing the state-run crop marketing corporations to make them less corrupt, more efficient, and more accountable; and, certainly not least, expanding family planning services.

Policy changes carry the risk of significant political ramifications—the Sudanese government, for instance, was overthrown in April 1985, partially as a result of raising the price of bread—but they can also have dramatic positive results. Zimbabwe, one of the few African countries with effective pricing policies, produced a corn surplus of 800,000 tons in 1985, allowing it to provide 25,000 tons of grain as emergency food aid to Ethiopia.

RECENT DEVELOPMENTS

FAMINE IN AFRICA

In 1984 and 1985, Africa was the scene of both overwhelming human tragedy and its most stirring triumph, as first a terrible famine enveloped much of the continent and then a massive outpouring of world food aid was mobilized to save many from starvation. Very likely more than 1 million Africans died from malnutrition and related diseases, particularly in Sudan, Ethiopia, Niger, Mozambique, Somalia, Chad, and Mali, but millions more were saved by over $1 billion worth of food and aid donations from around the globe.

Both the famine and the relief effort were haunting repetitions of a similar catastrophe that struck the continent in 1973–74. Although the recent relief campaign was bigger, better-coordinated, and included for the first time the significant involvement of non-government organizations, the agricultural debacle was stark proof that, on the policy level, little had been learned since the previous famine. While in the short term the international community responded effectively to the crisis, in the long term, business-as-usual in African development

Box 4.3 High-Input vs. Low-Input Agriculture

Because of the phenomenal food production record of the United States, there is a widespread presumption that agricultural technology and methods that worked in the United States and other developed countries are the logical ones for the rest of the world to use. Because farmers and policymakers acted on this presumption, much of the world's agricultural diversity—hardy genetic varieties, specialized appropriate tools, and locally suited cropping strategies—is disappearing or has already been lost.

The post-World War II green revolution took U.S.-style high-input agriculture and applied it to the developing world. By selectively breeding high-yield, fast-growing wheat, rice, maize, and other foods, scientists opened a huge new supply of nourishment, but at a price. The new varieties are so specialized that they are finicky and vulnerable, and need large quantities of water, fertilizers, and biocides to perform. In some regions of the world, notably South Asia and East Asia, the new varieties were highly successful. Other regions either did not have the financial resources or infrastructure to participate in the green revolution, or did not have environments conducive to the specific crops and genetic traits scientists had developed. With no other strategy for agricultural development, the rate of food production growth in these countries stagnated.

Ironically, while the rest of the world was trying to emulate the United States, a profound change in American farming philosophy began to emerge in the late 1970s (1). After years of striving to increase production at any cost, a few farmers realized that some of those costs were simply too high: that ever more-expensive chemical and technological imputs weren't worth the added output. The new philosophy contends that profitability rather than production should be the bottom line, and in making that switch farmers are beginning to adopt some of the policies environmentalists had advocated for years. For instance:

- Since the development of chemical agriculture, farmers have been encouraged to use pesticides heavily, attempting to wipe out pest populations. Because of the pressure of rising chemical and environmental costs—including accelerating pest resistance—the new philosophy espouses integrated pest management, a more environmentally sound combination of techniques usually involving smaller quantities of chemical pesticides applied more appropriately and attempts to reduce pests only to a level below that which could destroy a financially significant percentage of the crop.
- For many years, farmers were told that yields could be increased and erosion compensated for by heavy applications of synthetic fertilizer. In fact, the development of synthetic nitrogen fertilizer in the 1940s allowed U.S. farmers in the Corn Belt to eliminate their erosion-controlling legume rotation and shift to permanent corn and soybean cropping. But as petroleum-based fertilizer prices skyrocketed, the new philosophy revived old-fashioned ideas of soil husbandry, including mulching, strip cropping, and terracing, as well as removing steep and marginal land from production.

In the United States and elsewhere, the new lower-input approaches have not meant less technologically sophisticated farming; indeed, the new methods may be more sophisticated. In general, these new approaches have meant a departure from mankind-over-nature agriculture. Often they involve a shift from an exclusive focus on yield to one that considers other factors such as hardiness, efficiency, and resilience. The fact that a new lower-input philosophy could emerge in the United States may presage a flowering of alternative agricultural approaches more appropriate to the many diverse regions, climates, soils, and financial resources of the developing world.

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proved in many respects to have been a conspicuous failure.

The nation most closely identified with the famine in the public's mind was Ethiopia, although starvation hit earlier in Mozambique, and more people were actually at risk in Sudan. All told, the FAO identified 20 sub-Saharan nations facing serious food shortages in 1985, with about 30–35 million of their 200 million citizens severely affected. By March, 1985, about 10 million persons had been forced to abandon their homes and lands in search of food, water and pasture for their rapidly declining herds.

The Ethiopian drought began in 1982, and starvation deaths were reported in early 1984. Despite persistent efforts by various relief agencies and U.N. personnel to generate publicity, the crisis was all but ignored until first British and then U.S. television footage shocked the public into action. Then the response was dramatic.

Between early April and late September 1985, the international community made available 5.6 million metric tons of cereals and 441,000 tons of non-cereal foods, worth over $1 billion. By October 1, $590 million worth of non-food aid had also arrived or been pledged: equipment and services to help with logistics, health, water supply and sanitation, and agricultural inputs.

A notable aspect of the relief effort was the unprecedented involvement of non-governmental organizations, both as catalysts and as actual aid donors. The music and entertainment industry in the United States and Great Britain was extremely active, creating USA for Africa, which generated over $50 million from the sale of a special album and videotape, "We Are The World"; the Band Aid Trust, which distributed $15 million raised by the hit record, "Do They Know It's Christmas?"; and the Live Aid Foundation, which pulled in more than $65 million through a two-continent televised fundraising concert. Numerous other private agencies took part as well, including the International Committee of the Red Cross, CARITAS, Radda Barnen, OXFAM, Interaction, Catholic Relief Services, CARE, Médecins sans Frontiéres, Danish Church Aid, American Jewish World Services, and the Islamic African Relief Agency.

Of course, the lion's share of the relief effort was financed by national governments, 90 of which had pledged or provided aid by the end of 1985. Of symbolic importance, 18 donor nations were African countries, many of them drought-stricken themselves. Perhaps most dramatic was the commitment by Italy, previously only a tiny aid provider, to give almost $1 billion to the world's poorest nations over an 18-month period. The policy shift placed Italy near the top of the list of world donors.

The entire relief effort was coordinated by the United Nations Office for Emergency Operations in Africa, which had to cope with a mind-numbing variety of logistical problems. Soliciting food, in fact, was much less a problem than was getting it to isolated communities and refugee camps. Few African ports, for instance, are equipped for huge emergency operations: port congestion in Assab, Ethiopia led to 12-day delays, while the single wharf serving Mauritania's capital city of Nouakchott had a 30-day berthing delay. Once food is unloaded, many countries have insufficient infrastructure to distribute it: Ethiopia's Djibouti-Dire Dawa-Addis Ababa railroad line lost the services of about 25 percent of its locomotives and freight cars, while Sudan's Kosti-Nyala Railway did not function at all until September 1985. Of course, the situation was made much worse in countries like Mozambique, Angola, and Ethiopia, by armed insurrection and sabotage.

By the autumn of 1985, rainfall had increased over much—but not all—of the continent, and some of the refugee camps were begining to empty. Localized pockets of hunger and even starvation still remained, and there were projections that large amounts of food aid would again be needed in Ethiopia and elsewhere in 1986, but the critical point of the crisis had apparently passed. Africa now would face the long, difficult task of rebuilding its agriculture, its health, and its strength.

WOMEN AND AGRICULTURE

In July 1985, at the end of the Decade for Women, the World Conference to Review and Appraise the Achievement of the U.N. Decade for Women was convened in Nairobi, Kenya. The conference's product, a "forward-looking strategies" document focused much of its attention on the issues of food, agriculture, water, energy and environmental management to achieve sustainable development.

Most of the world's farmers are women. Eighty-five percent of Africa's food production is produced by women. The capacity of the soils, the quality and availability of water, the effects of chemicals and pesticides therefore rightly commanded as much attention as traditional "women's issues."

As in previous conferences, there was intense debate on many issues, but in the area of natural resource and environmental management as they relate to food production, there was absolutely no dissent. These issues, in fact, forged the common ground among women in both the official conference and the Non-Governmental Organizations (NGO) Forum held concurrently at the University of Nairobi and attended by 10,000 women.

The 3,000 women representing their governments at the official conference demanded that development programs addressing agricultural productivity involve the full participation of women from initial planning to final implementation. Many delegations, both in their government position papers and in plenary speeches, noted that drought and desertification are aggravated by inappropriate agricultural and water development projects, and by the emphasis on urban, as opposed to rural, development. Other central themes cited as hindering full agricultural productivity were the widespread discrimination against women in the ownership of land, and the lack of access to economic resources to enable women to use alternative energy systems.

Another concern was the mechanization of agriculture, because in many cultures machinery is perceived as inappropriate for women to use. There was strong dissent over the emphasis on commercial agricultural production for export, as opposed to small-scale farming to produce family food. The aggregation of lands for producing cash crops rather than for feeding indigenous populations was perceived to be the result of the heavy international debts many developing countries confront. The disenfranchisement of women in many countries from agricultural development planning and implementation led to several sections in the strategy documents and resolutions addressing these concerns (76). These point out that agricultural development projects that exclude those—the women—who do the bulk of the labor often fail. Conversely, projects directed to those most intimately involved—such as the grassroots tree-planting Green Belt Movement in Kenya—can be conspicuously successful.

THE SEED WARS

The simmering struggle over agricultural seeds escalated in late 1985 with the decision by the FAO to establish a new worldwide system of seed banks that would operate under significantly different rules from those of the existing non-U.N. facilities.

These gene banks are currently under the control of the International Board for Plant Genetic Resources (IBPGR), which is part of the Consultative Group for International Agricultural Research (CGIAR). In turn, CGIAR is cosponsored by the World Bank, the FAO, and the United Nations Development Program (UNDP). Behind this alphabet soup of agencies is a real and bitter controversy over who should control the genetic wealth found largely in developing countries: the rich nations with their high-technology laboratories and trained researchers, or the poor tropical nations, which provide the scientists' raw material.

For thousands of years, mankind has been improving natural and primitive agricultural varieties, seeking crops that are higher yielding, faster growing, better tasting, more disease- and pest-resistant, more nourishing and otherwise superior. The pace has picked up markedly since World War II and rose even more with the advent of genetic engineering techniques. There are now hybrid varieties of rice and wheat that are scores of times more productive than their ancient purebred ancestors. Naturally, there is great profit in the development, patenting, and sale of these improved seeds, even though the germ plasm (seeds, rootstock, and plant tissue) is collected largely free of charge from many of the nations that may later be forced to pay high prices for proprietary seeds. On the other hand, much of the benefit from crop improvements developed by CGIAR has gone to the developing countries as part of the Green Revolution.

The genetic wellspring of the world's agriculture is located largely in the tropics and the southern hemisphere—what is now still the developing world. The potato is native to the Andes, corn to Mexico, coffee to Africa, and wheat to Ethiopia. The Third World still has tens of thousands of wild varieties of these and other crops with genetic characteristics that could improve present crops, and that will be needed to adapt current varieties to future conditions.

As a form of protectionism, some developing countries have clamped down on the free utilization of their genetic resources; Cuba, for instance, bans the export of tobacco seed, and Ethiopia forbids shipment of coffee seed. The answer does not appear to lie in trade restrictions, however, since both North and South benefit from seed improvements and from the safest possible storage of precious seed stock no longer found in the wild.

The recent decision attempts to shift the balance of power in the direction of the developing nations in three significant ways:

1. Instead of the current ad hoc, informal structure of CGIAR, the seed banks would become an official part of the FAO (and, hence, the United Nations), in which Third World nations have a voting majority.
2. For the first time, there would be a fund for training Third World scientists in genetic research (though many have been trained under the present system).
3. Most important, the patenting of new seed varieties would not be allowed and all countries could make use of new varieties without charge.

However, most of the developed nations (including the United States, which provides 25 percent of FAO's budget) are satisifed with the present system and feel that the charges of "genetic imperialism" being leveled against them are without merit. They are so strongly opposed to the proposed new banks that they are threatening not to join or fund the system. Such an action could result in two parallel seed bank structures, or it could so undermine the new proposal that it would collapse before it starts.

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67. L.R. Brown and E.C. Wolf, *Reversing Africa's Decline*, Worldwatch Paper #65 (Worldwatch Institute, Washington, D.C., June 1985), p. 20.
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70. The World Bank, *World Development Report 1985* (The World Bank, Washington, D.C., 1985), Table 19.
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74. M. Strong, "Beyond the Famine—New Hope for Africa," David Davies Memorial Lecture (Institute of International Studies, London, 1985), p. 9.
75. U.S. Department of State *Africa: The Potential for Higher Food Production*, Special Report No. 125 (Washington, D.C., April, 1985), p. 1.
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5. Forests and Rangelands

Forests cover roughly one third of the world's land area. Wood and forest products provide income and employment for millions, essential raw materials, and fuelwood, which is the main source of household energy in the developing world. Worldwide, trade in forest products exceeds $100 billion annually.

Rangelands (1) represent another important land use, especially in arid and semi-arid regions. These lands, which cover almost half of all ice-free land, include various vegetation types from arctic tundra to alpine meadows and tropical and temperate grasslands. On some lands, grass grows under a sparse tree canopy. These are sometimes counted as rangelands and sometimes as "open forests."

In many countries forests and rangelands are poorly managed and their productivity is declining. Some countries, particularly in Africa and South America, are pushing forest and range resources to their ecological limits. Managers often lack the data needed to make sound decisions. Though both these ecosystems suffer from a lack of good information, the data on range resources are especially poor. Comparatively, analysts can put much more stock in forestry statistics than in rangeland data.

CONDITIONS AND TRENDS

FOREST RESOURCES

Before large-scale disturbances by humans, the world's forests and woodlands probably covered 6 billion hectares. By 1954, the total had declined to approximately 4 billion hectares. This 30 percent reduction reflects the increasing use of land for agriculture, pasture, and settlements. (See Part IV, "Land Use and Cover," Table 4.2.)

Worldwide, about 2.8 billion hectares (or 69 percent of the forested areas) are covered with closed forests (2), and 1.3 billion hectares are less densely wooded open forests. Forest regrowth on fallowed cropland covers an additional 406 million hectares, and natural shrublands and degraded forests in developing countries cover 675 million hectares. When these two categories of wooded land are added to open and closed forests, the total (5.2 billion hectares with woody vegetation) represents about 40 percent of the world's total land area. (See Table 5.1.)

Trees outside forests that are in windbreaks, along rights-of-way, or around farm fields, etc., are also important resources, especially in densely populated areas. Some 20 percent of Rwanda's farmland is maintained by farmers as woodlots and wooded pasture. These roughly 200,000 hectares of dispersed trees exceed the combined area of the country's remaining natural forests and state and communal plantations (3). In the Kakamega District of Kenya, over 90 percent of the farms have scattered tree cover, 79 percent of the farmers plant trees, and 64 percent of the farms have woodlots (4). Of the 7.2 billion trees planted in the densely settled plains region of China, 5.8 billion have been planted around homes and in villages, with each household tending an average of 74 trees (5). Even in France, where trees are not used for

Table 5.1 Distribution of the World's Forest Lands, 1980 and 1985

(millions of hectares)

Region	Total Land Area	Closed Forest		Open Forest	Total Forest Area	Percent of Total Land Area Forested	Other Wooded Land		Total Wooded Area[d]	Percent of Total Land Area Wooded
		Broadleaved[a]	Coniferous				Shrubland[b]	Forest Fallow[c]		
1980 World Totals	**13,077[e]**	**1,827**	**1,121**	**1,372**	**4,320**	**33**	**624**	**407**	**5,381**	**41**
1985 World Totals	**13,077**	**1,726**	**1,139**	**1,282**	**4,147**	**32**	**675**	**406**	**5,228**	**40**
North America[f]	1,835	168	301	215	684	37	X	NA	684	37
Europe	472	65	88	21	174	37	X	NA	174	37
USSR	2,227	147	645	128	920	41	X	NA	920	41
Other Countries[g]	950	50	22	70	142	15	X	NA	142	15
Developed Countries Subtotal	**5,484**	**430**	**1,056**	**434**	**1,920**	**35**	**X**	**NA**	**1,920**	**35**
Africa	2,966	216	2	500	718	24	450	160	1,328	45
Latin America	2,054	666	26	250	942	46	150	170	1,262	61
Asia (except China and Oceania)	1,640	317	30	83	430	26	45	76	551	34
China	933	97	25	15	137	15	30	X	167	18
Developing Countries Subtotal	**7,593**	**1,296**	**83**	**848**	**2,227**	**29**	**675**	**406**	**3,308**	**44**

X = not available
NA = not applicable

Notes:

a. Includes bamboo and mangrove formations.
b. Includes area with woody vegetation greater than 0.5 meters and less than 7 meters in height counted by the Food and Agriculture Organization as "other land" (see Table 5.12).
c. Includes wooded areas with forest regrowth following clearing for shifting cultivation within the past 20 years.
d. Includes forest area and other wooded land.
e. "World totals" exclude Antarctica.
f. Canada and the United States.
g. Australia, New Zealand, Japan, Israel, and South Africa.

Sources:

1. For 1980 world totals: U.N. Food and Agriculture Organization (FAO), 1985. Reference 10.
2. For 1985 world totals: R. Persson, unpublished report to Swedish International Development Authority (1985), Tables 1, 2, and 4.
3. For total and regional land area: (FAO), 1984. Reference 13.

fuelwood, trees outside the forest occupy 883,000 hectares, or 6 percent of the country's forested land. (6).

Excluding forest fallow, shrubland, and trees outside the forest, closed forests and open woodlands still cover three times as much area globally as croplands and 75 percent more than grasslands (7). Today, forests and woodlands account for 66 percent of the net primary productivity of terrestrial ecosystems; of that productivity, tropical forests account for 75 percent (8).

The world's coniferous forests, the source of most industrial wood production, cover 1.4 billion hectares. Some 85 percent of them are in North America and the USSR. Non-coniferous (9) forests cover 2.8 billion hectares, or 67 percent of the world's forest area. About 1.6 billion hectares of these forests are found in South America and Africa, with another 600 million hectares in Asia and Oceania (10). (See Figure 5.1.)

Forests in temperate regions cover approximately 2 billion hectares, with 75 percent (1.6 billion hectares) of these forests categorized as closed (11). Closed tropical forests cover about 62 percent of the area of tropical forests (12). Slightly more than half the world's forests are in developing countries, where they cover 2.3 billion hectares, or 30 percent of the land area (13). In developed countries, forested areas amount to approximately 1.8 billion hectares or about 34 percent of these countries' land area (14).

Tropical forests—including closed forests, open forests, shrubland, and forest fallow—cover nearly 3 billion hectares worldwide. An area roughly equal to one fifth of closed and open tropical forests now lies fallow—the result of clearing by shifting cultivators within the past 20 years. Closed broadleaved coniferous and bamboo forests in the tropics covered 1.2 billion hectares in 1980 (15). Latin America includes the largest expanses of closed tropical forests. Two thirds of all open tropical forests are in Africa. The percentage of wooded land is lowest in tropical Asia (47 percent).

Forest resources are divided unevenly among countries, reflecting great variations in rainfall, temperature, land use, total land area, and population density. The Soviet Union has the largest area of forest (928 million hectares). Fifty-two percent of the world's closed tropical forests are found in Brazil, Indonesia, and Zaire. Together the 25 most extensively forested countries, which comprise 45 percent of the world's population, include 3.2 billion hectares (74 percent) of the world's forest area. The Soviet Union, Canada, and the United States together have 1.7 billion hectares, or nearly 54 percent of the world total. (See Table 5.2.)

Changes in Forest Distribution

Evaluating long-term trends is difficult without more and better data on forest resources. But one recent assessment (16) indicates that, historically, the greatest relative changes in the vegetation cover have occurred in temperate regions. Since large-scale land clearing for agriculture began around 8000 B.C., grasslands have been reduced by 45–47 percent, and cold-deciduous forests (evergreen and temperate evergreen seasonal broadleaved forests) have been reduced by 32–33 percent. (See Part IV, "Land Use and Cover," Table 4.2.) In contrast, most types of natural climax tropical vegetation have been reduced in area by 15–20 percent over the past several millenia. Some 24–25 percent of all wooded savannas and tropical/subtropical deciduous forests have been cleared, while until recently only slight losses (4–6 percent) of tropical evergreen rainforests and tropical/subtropical evergreen needle-leaved forests have occurred.

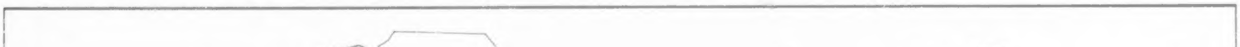
Changes in forest areas in the tropics have far outstripped those in temperate regions. Temperate forests in Europe, Asia, and Oceania have grown slightly over the past few decades because reforestation and reversion of cropland to forestland have more than offset losses to urbanization, roads, and other uses. In North America, the total forested area increased steadily in the early 20th Century, after centuries of decline. More recently, however, the total has again dropped slightly. In contrast, the area of forests and woodlands declined from 115 to 71 million hectares in Central America and from 901 to 690 million hectares in Africa between 1950 and 1983 (17).

Of course, aggregate changes obscure differing trends among and within different countries. Estimates of forest area reveal little about the condition of forest resources (e.g., changes in the density of the tree cover or in the productivity or composition of forests). In general, as long as tree cover appears to exceed 10–20 percent, an area is considered forested, even though the forest may have been significantly degraded and the number of trees per hectare reduced from several hundred to less than 50.

Comparatively good data make changes in Europe's forest area relatively easy to examine. (See Figure 5.2.) Net increases in forest area over the past few decades, despite high population densities and land use pressures, are largely the result of increased productivity on farmlands. This productivity, coupled with greater public recognition of forests' economic and aesthetic values, has been complemented by tax incentives and other support programs designed to sustain or increase domestic wood supplies, the growth of forest product imports, and the efforts to keep forests as part of the landscape (18). For example, Turkey planted 150,000 hectares a year during the 1970s while Finland drained and afforested peat lands and restocked other wooded lands and once-abandoned cropland. In Norway and Sweden, reduced grazing pressure and the release of agricultural land, together with government reforestation programs, have greatly increased the overall forest area. In Ireland and the United Kingdom, similar increases stem from government and private tree-planting activities, which amounted to 10,000 hectares in Ireland and 30–40,000 hectares in the United Kingdom annually in the late 1970s and early 1980s. In Hungary, Czechoslovakia, and the Netherlands, reforestation programs also significantly boosted forest area. Even where net changes have been insignificant, compensating changes in land use often mask reforestation and forest renewal. For example, recently the Federal Republic of Germany has been losing about 10,000 hectares of forestland each year to urbanization and other developments, but it has been reforesting marginal agricultural land even faster (19). In the United States, however, forest area has been gradually decreasing as a result of conversion to cropland, urbanization, water impoundments, mining, and other uses of forestland. Between 1963 and 1980, total forest area in the United States declined from 307 to 290 million hectares (20).

In tropical regions, deforestation rates have exceeded reforestation by 10–20 times in recent years. Average annual deforestation is greatest in Latin America, especially in the unproductive (21) and logged-over closed forests of the tropics. Deforestation rates are also high in

Figure 5.1 Main Vegetation Zones of the World's Forests


☐ Cool Coniferous Forest
☐ Temperate Mixed Forest
☐ Warm Temperate Moist Forest
☐ Tropical Moist Evergreen Forest
☐ Tropical Moist Deciduous Forest
■ Dry Forest

Source: U.N. Food and Agriculture Organization (FAO), *Unasylva*, Vol. 28, No. 112-113 (1976).

Africa's open forests. In the unproductive closed forests of Africa and Asia, deforestation rates have been relatively low: in 1980, losses equaled about 0.6 percent of remaining forests in all three regions, though exact amounts and rates varied more than a hundredfold among countries.

A driving force behind the loss of forestlands has been the conversion of forests to agricultural land. Since 1976, 6–8 million hectares of closed forests and nearly 4 million hectares of open forests and woodlands have been cleared each year for agriculture (22). Annually, 4–5 million hectares of productive closed forests are logged, and over 90 percent of this area later becomes cropland. Another 14.5 million hectares of forest fallow are cleared each year; of that fallow, 3.3 million hectares are converted to permanent agriculture and the remainder returned to forest fallow by shifting cultivators (23).

Productivity and Growing Stock of Forests

About two thirds of all closed forest is commercially exploitable. In Europe, 133 million hectares (92 percent) of the closed forests are considered commercial, of which 121 million hectares are stocked (24). In the United States, 195 million hectares (65 percent) of closed forests are commercially productive, and 189 million hectares are stocked. By contrast, 886 million hectares (74 percent) of closed tropical forests are considered productive, while 274 million hectares of closed forests and 369 million hectares (50 percent) of open forests are either poorly stocked or are inaccessible (25).

The available data suggest that, worldwide, the growing stock of commercially exploitable living trees has decreased slightly, whereas the amount of wood harvested has steadily increased. Forest regrowth in temperate climates has masked decreases in the tropics. For example, 169 million hectares (or 20 percent) of all productive closed forest in tropical countries has already been logged (26). The United Nations Environment Program (UNEP) reported in 1982 that only 400 million hectares (10 percent) of the world's forestlands are sufficiently well-stocked to yield more than half their potential production. Yields on 3.3 billion hectares (80 percent) of the world's forestlands are estimated at less than 20 percent of the potential maximum as a result of depletion of growing stock, erosion, and site degradation (27).

FOREST MANAGEMENT

In the early 1960s, the U.N. Food and Agriculture Organization (FAO) estimated that management plans had been prepared for 975 million hectares (23 percent) of the world's forests (28). Most areas were not being "intensively managed" (29), but logging practices had been prescribed and some provision made for post-harvest regeneration. Currently, less than 25 percent of the world's forests are actually managed, and most of them are in the Soviet Union. In tropical countries, intensively managed forests have decreased in area over the past two decades.

The depletion of natural forests in Europe and the United States in past centuries prompted vigorous efforts to renew and sustain supplies of wood fiber. As a result, 83 million hectares (58 percent) of Europe's closed forests are now managed according to a plan, and another 40 percent are subject to controls on use (30). In the Soviet Union, all 791 million hectares of closed forests, which are publicly owned, reportedly have management plans. (See Table 5.3.)

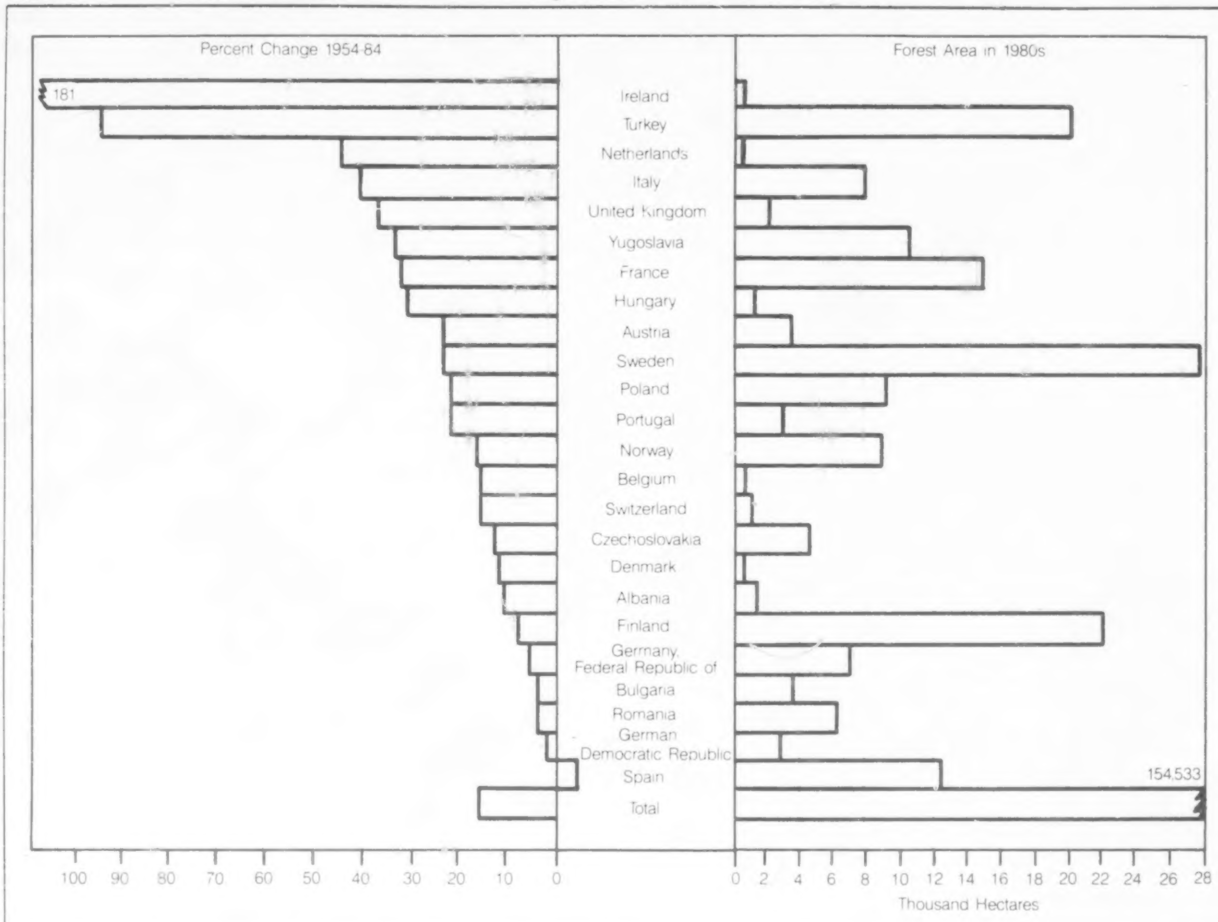
Table 5.2 Forest Areas in Selected Countries, 1980

Country	Forest Area (thousand ha)	Percent of Total Land
Countries with Large Areas of Forest		
USSR	928,600	41.5
Brazil	553,030	65.0
Canada	436,400	43.7
United States	298,076	31.8
Zaire	177,815	75.8
China	170,000	17.7
Indonesia	126,235	66.3
Countries with High Percentage of Forested Land		
Peru	71,640	55.7
Bolivia	66,763	60.8
Paraguay	30,360	74.6
Guyana	18,512	86.1
Suriname	15,605	95.6
Ecuador	14,679	51.8
Central African Republic	35,895	57.6
Botswana	32,560	54.2
Cameroon	25,805	54.3
Congo	21,508	62.9
Gabon	20,765	77.6
Senegal	11,170	56.9
Papua New Guinea	38,392	83.2
Malaysia	21,256	64.5
Laos	13,735	58.0
Kampuchea	12,716	70.2
Japan	25,280	67.9
Finland	23,225	68.9
Countries with Low Percentage of Forested Lands		
Libya	460	0.3
Algeria	2,990	1.3
Niger	2,960	2.3
South Africa	4,150	3.4
Tunisia	750	4.6
Kenya	3,860	6.6
Mali	8,819	7.1
Saudi Arabia	1,200	0.6
Syria	420	2.3
Afghanistan	1,500	2.3
Iraq	1,910	4.4
Israel	100	4.8
Pakistan	4,080	5.1
Iran	12,400	7.5
Haiti	58	2.1
Uruguay	580	3.3
El Salvador	155	7.4
Ireland	380	5.4
United Kingdom	2,178	8.9
Netherlands	355	9.5

Source: U.N. Food and Agriculture Organization (FAO), 1985. Reference 10.

Nevertheless, management problems persist in developed countries. Fire, insects, and disease still damage up to one quarter of the estimated annual increment in temperate forests. Air pollution and acid precipitation stunt growth rates and increase tree mortality in the United States, Sweden, Federal Republic of Germany, Finland, Poland, East Germany, and Hungary. (See Part III, Chapter 12, "Multiple Pollutants and Forest Decline.") Furthermore, some mixed forests in developed countries have been converted to plantations of commercially valuable coniferous species at the expense of wildlife habitat, the production of non-wood products (e.g., berries, nuts, etc.), soil fertility, and watershed protection.

Figure 5.2 Changes in Forest Areas in Europe, 1954-84



Sources:
1. U.N. Food and Agriculture Organization (FAO). *1955 Production Yearbook* (FAO, Rome, 1955).
2. Economic Commission for Europe (ECE)/Food and Agriculture Organization (FAO). *The Forest Resources of the ECE Region* (ECE, Geneva, 1985).

In developing countries, comparatively less forestland is managed. According to UNEP and the FAO (31), only five countries in Africa and four in Asia have significant areas of "intensively managed" forests. In 1960, harvesting regulations, working plans, and silvicultural treatments were conducted on 4–4.5 million hectares of closed forest in ten African countries, and management plans were prepared for another 6 million hectares. Today less than 2 million hectares, or barely 1 percent, of productive forests in Africa remain managed. Three quarters of them are in Ghana and Uganda, where political and economic turmoil undermine long-term management. Small areas (50–70,000 hectares) are under management in Kenya and Sudan. Working plans prepared for Cameroon and Gabon in recent years have yet to be implemented.

As in Africa, Latin America's managed forests have declined sharply—from 2.4 million hectares to 522,000 hectares—since the early 1960s. Management plans prepared for forests in Peru, Brazil, Belize, Paraguay, and Guatemala have not been implemented. Only in Nicaragua, Cuba, and Trinidad and Tobago and in small experimental forests in Costa Rica, El Salvador, Suriname, and Colombia are intensive forest-management practices used.

In Asia, the area of managed forests has increased slightly since the early 1960s from 37.3 to 39.7 million hectares. However, 80 percent of Asia's managed forests are in India, where 32.3 million hectares of forestlands were managed in 1964 and where about the same amount is managed today. Significant areas are also managed in Burma, Malaysia, and Bangladesh. In Pakistan and some other Asian countries, selective felling, periodic thinning, and occasional timber-stand improvement are practiced. Management plans prepared for 3 million hectares in the Philippines and 360,000 hectares in Indonesia in the early 1960s have not yet been implemented.

As for productive closed tropical forests, only 42 million out of 886 million hectares, or less than 5 percent of the global total, are currently managed (32). The reasons are a lack of political commitment in the face of pressure to convert these lands into farmland and pasture, the mistaken perception that economic returns from alternative land uses are always higher, and limited experience with tropical silviculture (33).

Protected Forest Areas

Over the past century, forest areas—mostly in the tropics—comprised some 65 percent of all the lands set aside for scientific study, fish and wildlife management, watershed protection, pasture, recreation, and various combinations of these uses. (See Table 5.4.)

According to the International Union for Conservation of Nature and Natural Resources (IUCN), by 1985 the area of protected tropical humid forests stood at 39.1 million hectares distributed among 280 reserves and protected areas—up from 23.1 million in 1974 (34). The area of tropical forests legally reserved in parks and other areas where industrial wood production is prohibited was 85.7 million hectares (4.4 percent) of the forested areas of 76 tropical countries. The proportion of protected forest land is lowest in tropical America and highest in Africa, where large expanses of woodland are included in national parks. Tropical Asia has the highest proportion of protected closed forest (5.8 percent), tropical America the lowest (2.1 percent). (See Table 5.5.)

In the developing world, many of these legally protected and reserved lands are still threatened by poaching, illegal timber harvesting, wildfires, and encroachment. At the same time, many threatened forest types have yet to be protected in parks and preserves—among them are the Malagasy thorn forest, the Sri Lankan rainforest, the Burman rainforest, and the Chilean Araucaria forests. Tropical forest areas in particular need of protection include Madagascar's eastern forests, the southeast Atlantic coastal forests of Brazil, the Choco region of Colombia, and the remaining forest in Costa Rica, Nicaragua, and Panama (35).

Table 5.3 Management of Closed Forests

(thousands of hectares)

Region/Country	Total Area of Closed Forest[a]	Area of Productive Closed Forest[b]	Area under Management Plans, 1963	Area under Management Plans, 1983
Europe	145,486	133,304	93,010	83,484
Soviet Union	791,600	534,500	299,965	791,600
United States	195,256	189,961	84,378	102,362
Tropical Asia	305,510	200,989	37,370	39,790
Tropical Africa	216,634	163,033	10,610	1,735
Central America & Caribbean	110,895	74,726	913	522
Tropical South America	567,760	446,925	1,531	0
World Total[b]	**2,333,141**	**1,743,438**	**527,777**	**1,019,493**

Notes:

a. Table does not include data on open forests in the regions listed; the forest areas of China, Canada, and other countries in temperate Asia, Africa, and Latin America are also excluded.

b. Closed forest that is suitable for industrial wood production (i.e., not commercial timberland).

Sources:

1. Data for tropical regions are from U.N. Food and Agriculture Organization (FAO), 1981, Reference 44, Tables 1c and 1d; FAO, 1981, Reference 49, Tables 1c and 1d; and FAO, *Los Recursos Forestales de la America Tropical* (FAO, Rome, 1981), Tables 1c and 1d, pp. 42–43.
2. Data for Europe and the Soviet Union are from: Economic Commission for Europe (ECE)/FAO, 1985, Reference 6, pp. 19–20.
3. Data for the United States are from the U.S. Forest Service, 1980, Reference 1, p. 366.
4. Data on area under management plans for 1963 are from: FAO, 1966, Reference 28.
5. Data on area under management plans for 1983 are from: FAO, Reference 44, Tables 1c and 1d; FAO, 1982, Reference 49, Tables 1c and 1d; FAO, *Los Recursos Forestales de la America Tropical* (FAO, Rome, 1981), Tables 1c and 1d, pp. 42–43; and ECE/FAO, Reference 6, Table 2.3.
6. Data for United States are estimated from commercial forestland in tree farms or owned by the U.S. Forest Service, Bureau of Land Management, state forest agencies, and forest industries. See U.S. Forest Service, 1980, Reference 1.

Table 5.4 Distribution of Protected Forested Areas by Biomes and Biogeographical Realms, 1985[a]

	Number of Protected Areas	Extent of Protected Area (millions hectares)
Forested Biomes[b]		
Tropical Humid Forests	280	39.1
Subtropical and Temperate Rainforests and Woodlands	275	22.4
Tropical Dry or Deciduous Forests or Woodlands	582	65.5
Evergreen Sclerophyllous Forests, Scrub, or Woodlands	475	12.0
Temperate Broadleaf Forests or Woodlands	484	11.5
Temperate Needle-Leaf Forests or Woodlands	173	38.8
Total	2,269	189.3
Forested Realms[b]		
Tropical Realms (Neotropical, Afrotropical, Indomalayan)	883	106.3
Temperate Realms (Nearctic, Palaearctic, Australian)	1,386	83.0
Total	2,269	189.3
Protected Forest Area as Percent of World Total[c]	65	44

Notes:

a. Includes all national parks and equivalent protected areas. Does not include game management areas, forest reserves managed for timber production, or forests managed for watershed protection.

b. Biomes are large and climatically uniform environments, each with its characteristic vegetation types. Biogeographical realms are geographical regions of the earth's surface, as defined by Udvardy.

c. While breakdown does not show desert, tundra, grassland, mountain, lake, and island biomes, these groups are included in the world total.

Source: International Union for Conservation of Nature and Natural Resources (IUCN), 1985, Reference 36.

Although the world total of protected lands doubled between 1970 and 1980, the amount of forestland reserved or protected in the developed countries has held steady in recent years (36). Some 66 million hectares, including nearly 20 percent of forestlands, have been set aside in the United States as part of the National Forest System (37). An additional 32 million hectares (38) are protected as national parks. Europe's closed forests include over 1.9 million hectares of national parks, and the total area of wooded land managed for protective functions rather than wood production or recreation amounts to 33 million hectares (or 23 percent) of all closed forests (39). The Soviet Union has designated 20 million hectares of its closed forests as national parks, and an additional 286 million hectares are managed as protected forests.

Reforestation and Forest Renewal

By 1980, 14.5 million hectares of forest land were being reforested or renewed worldwide every year (40). China currently leads the world in reforestation, planting annually more than five times the total area planted in all other developing countries. By 1965, after years of dramatic decline in China's forest area, the country was planting about 1–3 million hectares of trees each year; and by 1983–84, 13.2 million hectares had been planted.

According to official statistics, the Soviet Union had planted 11 million hectares by the early 1960s, and annual reforestation amounted to 4.5 million in 1980. However, the success rate of these plantations is not well documented. Large areas are also planted each year in the United States (1.8 million hectares per year), Canada (720,000 hectares per year), and Japan (240,000 hectares per year). Both North and South Korea plant over 150,000 hectares per year. The only other developing countries planting large areas are Brazil (346,000 hectares per year), Indonesia (187,000 hectares per year), and India (120,000 hectares per year). However, Chile (50,000 hectares per year), the Philippines (42,000 hectares per year), Argentina (38,000 hectares per year), and six other tropical countries are planting 10–50,000 hectares per year. Tropical developing countries (excluding China) annually plant 1.1 million hectares--roughly what Europe plants but less than 10 percent of the world total. Most developing countries plant 10–20 times less than what is needed to offset forest losses and meet increased demands for forest products.

As the investment costs of plantation establishment increase, the genetic quality of the planting stock has received more attention. Tree improvement, breeding, and tissue culture are being used increasingly in a number of countries to improve both the quality and quantity of wood produced from plantations. Yields from eucalyptus plantations in Brazil increased from about 22 cubic meters per hectare per year in the late 1960s to more than 60 cubic meters per hectare per year on experimental plots in 1981.

PRODUCTION AND TRADE OF FOREST PRODUCTS

Globally, the amount of wood harvested, or "produced," increased from 1.8 to 3.0 billion cubic meters per year between 1963 and 1983 (41). Most of the increase occurred in the developing countries as demand for fuelwood, sawnwood, wood-based panels, and paper rose. Similarly, total industrial wood removals declined slightly in developed countries but increased 40 percent in developing countries. Globally, increases in the harvesting of fuelwood accounted for 83 percent of the total increase in roundwood removals over the past ten years. (See Figure 5.3.)

The value of trade in forest products increased more rapidly in the 1970s than wood removals, thanks to more efficient and complete utilization of wood and to large increases in the manufacture and trade of paper and wood-based panels. From 1973 to 1983, the value of both forest product exports and imports increased by 113 percent. Slower growth rates in trade in recent years probably reflect the general economic slowdown and many developing countries' inability to import or export more forest products.

World trade in forest products now exceeds $100 billion annually, with $82 billion traded among the developed countries. Ten developed countries account for 65 percent of the total value of imports and exports. After important shifts in the last decade among net importers and exporters, Japan, the United Kingdom, Germany, Italy, and France still dominate imports, while net U.S. imports have become significant for the first time. Imports by China, Mexico, Venezuela, Argentina, Egypt, and Nigeria have also risen. Canada, Sweden, and Finland are still the major net exporters of forest products, but Malaysia has now surpassed the Soviet Union as the fourth largest net exporter. Brazil, Chile, Australia, and New Zealand have become more important exporters, while Gabon, Ivory Coast, and the Philippines have declined in importance (See Table 5.6.)

Fuelwood Production

In the mid 1940s, global production of fuelwood and charcoal was 634 million cubic meters, or about 52 percent of total roundwood production. Over the next 15 years, industrial wood production increased more rapidly than fuelwood production, and the share of fuelwood in total roundwood production steadily declined by the late 1950s to a low of 41 percent. But since then increased demand in developing countries has driven fuelwood and charcoal use up to 54 percent of total roundwood production. Indeed, though industrial roundwood production has nearly tripled over the past 35 years, fuelwood production increased even more. (See Table 5.7.)

In the developing world, 13 nations—the densely populated Asian countries of India, China, Indonesia, Bangladesh, Burma, Thailand, and the Philippines and the African countries of Nigeria, Tanzania, Sudan, Kenya,

Table 5.5 Protected Forests, 1980

Region/Country[a]	Total Forests (million hectares) Closed	Total Forests (million hectares) Open	Total Forests (million hectares) Total	Protected Forests[b] (million hectares) Closed	Protected Forests[b] (million hectares) Open	Protected Forests[b] (million hectares) Total	Percent of Area in Protected Forests Closed	Percent of Area in Protected Forests Open	Percent of Area in Protected Forests Total
Tropical Africa	217	486	703	9.3	42.0	51.3	4.3	8.6	7.3
Tropical America	679	217	896	14.1	2.1	16.2	2.1	1.0	1.8
Tropical Asia	305	31	336	17.6	0.6	18.2	5.8	1.9	5.4
Subtotal—76 Tropical Countries	**1,201**	**734**	**1,935**	**41.0**	**44.7**	**85.7**	**3.4**	**6.1**	**4.4**
Europe	146	35	181	1.9	20.4	22.3	1.3	58.3	12.3
USSR	792	138	930	20.0	138.0	158.0	2.5	100.0	17.0
North America	459	275	734	36.1	NA	36.1	7.9	X	4.9
Subtotal—ECE Region	**1,397**	**448**	**1,845**	**58.0**	**158.4**	**216.4**	**4.2**	**35.4**	**11.7**
Total	**2,598**	**1,182**	**3,780**	**99.0**	**203.1**	**302.1**	**3.8**	**17.2**	**8.0**

X = not available. NA = not applicable

Notes:

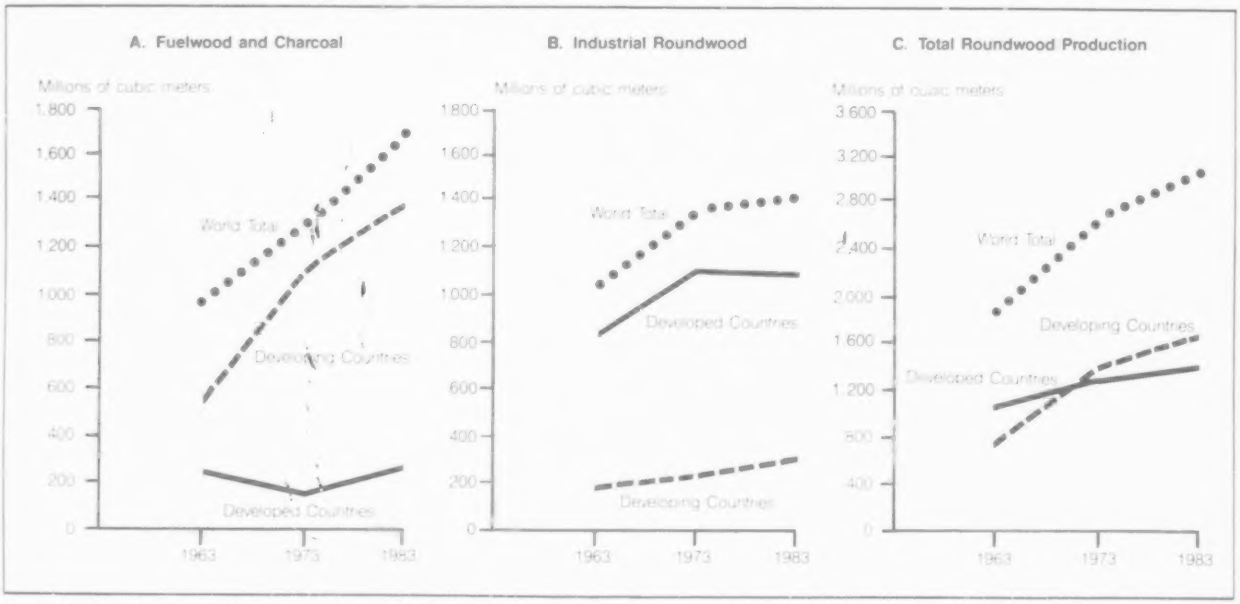
a. For tropical areas, includes natural parks, biosphere reserves, protected forests, and all other forest areas where industrial wood production is not authorized; does not include gazetted forest reserves where timber harvesting can be authorized. For the U.N. Economic Commission for Europe (ECE) countries, includes closed forest areas, designated national parks, and protected areas of open forests.

b. Does not include China, North Africa, temperate South America, South Africa, Near East, and Oceania.

Sources:

1. For tropical areas: U.N. Food and Agriculture Organization (FAO), 1982, Reference 12.
2. For all other areas: ECE/FAO, 1985, Reference 6.

Figure 5.3 Trends in Wood Production, 1973–83



Note: "Production" is wood removed through harvesting, not actual growth or annual increment of trees in forests.

Sources:

1. U.N. Food and Agriculture Organization (FAO), *Yearbook of Forest Products 1972–1983* (FAO, Rome, 1985), pp. 64–65, 78–79, 96–97.
2. U.N. Food and Agriculture Organization (FAO), *Yearbook of Forest Products 1963* (FAO, Rome, 1964).

Zaire, and Ethiopia—together consume more than 70 percent of the total global fuelwood. Brazil, Colombia, and Mexico are also major consumers. Between 1973 and 1983, fuelwood production increased 35 percent or more in Nigeria, Tanzania, Kenya, Uganda, Guatemala, El Salvador, and Nicaragua.

Fuelwood consumption has remained high in most developing countries because fuelwood is a versatile, mostly free source of household energy. (See Chapter 7, "Energy.") Today, 20 countries in Africa, 12 in Asia, and 7 in Latin America have less than 1.5 hectares of forestland per capita and consume 80 percent or more of total wood production as fuelwood.

Table 5.6 The World's Major Importers and Exporters of Forest Products, 1983

(millions of U.S. dollars)

Country	Exports (1983)	Imports (1983)	Net Trade
Canada	10,240	841	9,399
Sweden	4,713	433	4,280
Finland	4,161	305	3,856
Malaysia	2,175	213	1,962
USSR	2,557	965	1,592
Indonesia	976	209	767
Brazil	823	150	673
Austria	128	563	-435
Belgium-Luxembourg	851	1,353	-502
China	519	1,565	-1,046
France	1,263	2,532	-1,269
Netherlands	428	2,038	-1,610
Italy	519	2,914	-2,395
Germany, Federal Republic of	2,227	4,881	-2,654
United States	5,651	8,986	-3,335
United Kingdom	586	5,163	-4,577
Japan	734	6,064	-5,330

Source: U.N. Food and Agriculture Organization (FAO), 1985, Reference 41, pp. 333–[illegible].

Nearly 1.5 billion people in 63 countries, or about 60 percent of the people who depend on fuelwood as their principal source of energy for cooking and heating, are cutting wood faster than it can grow back. Fuelwood depletion is most serious in arid and semi-arid areas, where regrowth of shrubs and savanna woodlands is slow, and in cooler, mountainous areas, where the forest cover cannot rapidly recover from steady harvests of fuelwood. Nearly 100 million people in 22 countries (including 16 in Africa) cannot meet their minimum needs even by overcutting remaining forests. At present consumption rates, the estimated fuelwood deficit will double by the year 2000—the equivalent of 56 percent of current production in all developing countries. (See Table 5.8.)

The burden of collecting fuelwood and other biomass fuels has fallen mainly upon women and children, who must spend up to 300 workdays per year gathering each household's fuel. Where fuelwood is short, people often have no alternative but to burn grass, small twigs, bark, dried dung, crop residues, etc., even though such practices can contribute to soil erosion and reduce crop yields. In Nepal, diverting manure from the fields to the cookstove depresses grain yields by 15 percent (42). In Ethiopia, the dung that is used as household fuel has a fertilizer value of about $123 million per year and could increase grain harvests by 1-1.5 million metric tons annually (43).

In some areas, forest depletion has prompted tree planting, especially of multipurpose tree species. Eucalyptus poles are now being produced from planted seedlings by smallholders in Gujarat State in India,

Table 5.7 Production of Fuelwood and Charcoal among Major Consuming Countries

Country	1973 (millions of m^3)	1983 (millions of m^3)	Increase (Decrease)	Percent Change	Fuelwood as Percent of Total Roundwood Production 1981-83	Forest Area 1980 (hectares/person)
Nigeria	56.8	78.4	21.6	38	91	0.2
Tanzania	28.4	38.7	10.3	36	97	2.3
Kenya	18.8	27.9	9.1	48	95	0.2
Sudan	27.7	36.4	8.7	31	96	2.7
Zaire	21.8	28.8	7	32	92	6.2
Uganda	18.2	24.7	6.5	36	94	0.5
Ethiopia	22.7	27.9	5.2	23	95	0.9
Africa Subtotal	**312.4**	**414.4**	**102**	**33**	**88**	**1.6**
India	173.2	212.6	39.4	23	91	0.1
China	134.4	154.6	20.2	15	68	0.2
Indonesia	95.5	114.2	18.7	20	90	0.8
Thailand	28.5	36.2	7.7	27	89	0.4
Bangladesh	23.7	31.1	7.4	31	97	0.3
Philippines	21.8	28.5	6.7	31	79	0.3
Asia and Oceania Subtotal	**605.1**	**720.0**	**114.9**	**19**	**77**	**0.3**
Brazil	127.3	162.6	35.3	28	73	4.6
Mexico	9.9	13.3	3.4	34	67	0.7
Colombia	11.2	13.9	2.7	24	83	2.0
Guatemala	4.9	6.6	1.7	35	97	0.6
El Salvador	3.2	4.4	1.2	38	97	0.03
Latin America Subtotal	**197.1**	**253.5**	**56.4**	**29**	**73**	**2.7**
United States	17.3	101.9	84.6	489	24	1.3
Canada	3.5	5.5	2	57	4	18.1
North America Subtotal	**20.8**	**107.4**	**84.8**	**546**	**19**	**2.9**
Sweden	2.5	4.4	1.9	76	9	3.4
Italy	3.1	4.1	1	32	48	0.1
France	10.6	10.4	-0.2	-2	27	0.3
USSR	83.5	83.3	-0.2	0	23	3.5
Europe-USSR Subtotal	**158.9**	**245.5**	**86.6**	**54**	**20**	**1.5**
World Total	**1,273.6**	**1,632.9**	**359.3**	**28**	**54**	**1.0**

Note: U.N. Food and Agriculture Organization (FAO) statistics on fuelwood were incomplete prior to 1980, when new information became available as a result of a survey of fuelwood supplies in developing countries. Current "production" (or consumption) figures for fuelwood and charcoal may be somewhat high, as fuelwood has become scarce or unavailable in many areas, and principal consumers such as rural households in developing countries have been forced to substitute other fuels.
Source: FAO, 1985, Reference 41, pp. 78-79.

farmers in Haiti are planting trees to produce charcoal as a cash crop, and considerable supplies of fuelwood and poles are now produced in hedgerows and fallowed fields in Kenya and Rwanda. Home gardens also supply some family fuelwood needs in Sri Lanka, Bangladesh, and Indonesia (44). In the plains area of China, where 63 percent of the peasant households lacked firewood from four to six months of the year, the area of forests has been increased from 1.1 percent to 6.1 percent since 1949, and fuelwood scarcities have eased as a result. Most of the trees have been planted along rural roads and waterways, in farmland shelterbelts, and around homes, or they have been intercropped in fields (45).

Industrial Wood Production

Worldwide, industrial wood production amounted to 1.4 billion cubic meters in 1983, or 46 percent of total roundwood production, which is an increase of only 5 percent over global production in 1973. Over half the world's production of industrial wood is from the United States, Canada, and the Soviet Union. Other important producers that are increasing industrial wood production include Brazil, Paraguay, China, Malaysia, India, Nigeria, Zimbabwe, and South Africa. As a group, developing countries increased industrial wood production by 40 percent in 1973–83, to 89 million cubic meters.

Over the past decade, paper consumption increased about 2 percent each year in the developed countries. Today, the developing countries—three quarters of the world's population—consume less than one fifth of the world's paper, though this share is growing more rapidly (5.5 percent per annum) than in developed countries, as literacy, incomes, and population increase. Between 1970 and 1980, the developing countries' share of paper production rose from 7.8 percent to 12.4 percent of the world total; at the same time, their share of paper and paperboard consumption increased from 11 to 16 percent of the total.

Along with pulp and paper, logs for sawnwood and veneer are an important part of industrial roundwood production. The global annual production of hardwood sawlogs has hovered around 240 million cubic meters over the past decade; small production decreases in Europe, the Soviet Union, and North America have been offset by gains in developing countries, which have increased their share of global production from 47 percent to 56 percent since 1973. Production of hardwood sawlogs is dominated by eight developing countries and five developed countries that together produce 73 percent of the global production.

Increased domestic consumption and processing, along with legislated reductions in exports in some countries, have also contributed to declines in hardwood exports. Only Malaysia and Papua New Guinea have significantly increased exports of hardwood logs over the past decade. Exports from Africa declined from 8.3 to 4.8 million

Table 5.8 Fuelwood Deficits by Region, 1980 and 2000

Fuelwood Situation	Region	Populations Involved and Fuelwood Deficit in 1980	Countries Mainly Concerned[d]
Acute Scarcity[a] Arid and semi-arid areas	Africa	13 million people 6 million m^3	Burkina Faso, Cape Verde, Chad, Djibouti, Mali, Mauritania, Niger, Sudan, Kenya, Ethiopia, Somalia, Botswana, Namibia
	Asia	9.5 million people 3.6 million m^3	Afghanistan, Pakistan
	Latin America	6.8 million people 3.5 million m^3	Chile, Peru
Mountainous areas	Africa	36 million people 40 million m^3	Burundi, Rwanda, Lesotho, Swaziland
	Asia	29 million people 34 million m^3	Nepal
	Latin America	2 million people 2 million m^3	Bolivia, Peru
	Total	96.3 million people 89.1 million m^3	23 countries
Deficit[b] Areas with rapidly increasing population and agriculture	Africa	131 million people 66 million m^3	Cameroon, Congo, Zaire, Malawi, Kenya, Madagascar, Uganda, Tanzania, Gambia, Guinea, Benin, Togo, Senegal, Sierra Leone, Nigeria, Mozambique
	Asia	288 million people 75 million m^3	India, Nepal, Pakistan
	Latin America	143 million people 36 million m^3	Brazil, Colombia, Peru, Cuba, Dominican Republic, Guatemala, Mexico, Trinidad and Tobago
Densely populated lowlands	Asia	412 million people 120 million m^3	Bangladesh, India, Sri Lanka, Thailand, Indonesia (Java), Philippines, Vietnam
	Latin America	9 million people 6 million m^3	El Salvador, Haiti, Jamaica
	Total	983 million people 303 million m^3	37 countries
Prospective Deficit[c]	Africa	(in year 2000: 175 million people facing a 40 million m^3 deficit)	Ghana, Ivory Coast, Central African Republic, Angola, Zimbabwe, Guinea-Bissau
	Asia	(in year 2000: 239 million people facing a 50 million m^3 deficit)	Burma, India, Indonesia, Philippines, Vietnam
	Latin America	(in year 2000: 50 million people facing substantial degradation of fuelwood supplies)	Ecuador, Paraguay, Uruguay, Venezuela
	Total	464 million people	15 countries
Surplus Potential for Wood-Based Energy Low population tropical forest area	Africa	Surplus potential 50 million m^3	Cameroon, Congo, Equatorial Guinea, Angola, Zaire, Central African Republic
	Asia	Surplus potential 200 million m^3	Bhutan, Laos, Democratic Kampuchea, Indonesia (except Java)
	Latin America	Surplus potential 200 million m^3	Amazon Basin

Notes:
a. Acute scarcity: available supplies of fuelwood are insufficient to meet minimum requirements, even with overcutting.
b. Deficit: fuelwood supplies are being consumed faster than they are replenished by natural regeneration and forest growth.
c. Prospective deficit: fuelwood supplies will be in a deficit situation by the year 2000, if present trends continue.
d. Data not available for China.
Source: Adapted from U.N. Food and Agriculture Organization (FAO), "Fuelwood and Energy," Priority Action Program in Tropical Forestry (FAO Forestry Department, draft working paper, Rome, 1985).

cubic meters and exports from Latin America declined from 525,000 to 47,000 cubic meters between 1973 and 1983. The decline in both log production and exports has been particularly notable in Thailand, Indonesia, Philippines, Ivory Coast, Liberia, Congo, and Colombia. In Brazil, Cameroon, and Nigeria, increased local consumption has overshadowed production increases. Indonesia, Malaysia, Philippines, and Cameroon have increased domestic processing of sawlogs and exports of sawnwood.

In January 1985, Indonesia introduced a total ban on unprocessed log exports. Among the major producers that still export a large proportion of sawlog production are Papua New Guinea and Gabon, which export over 90 percent of their log production, and Liberia, Malaysia, and Ivory Coast, where log exports account for 50–60 percent of total sawlog production. Malaysia, Papua New Guinea, Philippines, Ivory Coast, and Gabon together account for 84 percent of the world's exports of hardwood logs.

Although the total volume of log exports has declined from 45 to 29 million cubic meters over the past five years, the value of hardwood log exports from developing countries increased from $1.9 billion in 1973 to a high of $3.8 billion in 1979, falling to around $2.6 billion annually in the 1980s. Developing countries still account for 90 percent of the world's hardwood log exports, and 64 percent of these exports now originate in Malaysia.

FOCUS ON: DEFORESTATION IN DEVELOPING COUNTRIES

Deforestation, perhaps the world's most pressing land use problem, commonly refers to the clearing of forest and its conversion to non-forest uses. Tropical forests provide humanity with a cornucopia of benefits. Tropical forests are living museums and laboratories that have yielded only a tiny fraction of their treasures to scientific study. Many useful chemical products essential for making medicines and pharmaceuticals originate in tropical plants. More than 50 percent of modern medicines come from the natural world, many from tropical forests, including: strychnine, ipecacuanha, reserpine, curare, and quinine.

Industrial products derived from tropical moist forests include volatile essential oils, gums, resins, latexes, and other exudates, steroids, waxes, rubber, fibers, dyes, tanning agents, turpentines, edible oils, rattans, bamboo, flavorings, spices, and pesticides.

Tropical forests protect watersheds and regulate water flow for farmers who grow food for well over 1 billion people. When upland watersheds are deforested, downstream hydropower reservoirs and irrigation systems suffer from siltation. Erosion and sedimentation of rivers cause flooding and enormous human suffering. Furthermore, rainforests are home to some 200 million people, who rely on the forests for the necessities of life. Tropical forests provide them with fruits, nuts, and honey, along with fibers and wood for building, fuelwood for cooking, lighting, and heating, and animal fodder for livestock raising.

Perhaps the most important aspect of tropical forests is their incredible array of life. During the ice ages, they served as refuges where less hardy species survived and later repopulated the temperate zones. Whereas temperate, northern forests are unlikely to contain more than 10–15 tree species per hectare, a single hectare of Amazon rainforest has been known to contain up to 230 tree species. Panama, for example, has as many plant species as all of Europe combined. And peninsular Malaysia has 7,900 species of flowering plants, compared with the United Kingdom's total of 1,430 species in twice the area. If tropical forests continue to be destroyed at current rates, the resulting ecosystem degradation could even generate local or regional climatic changes, with as yet unknown consequences.

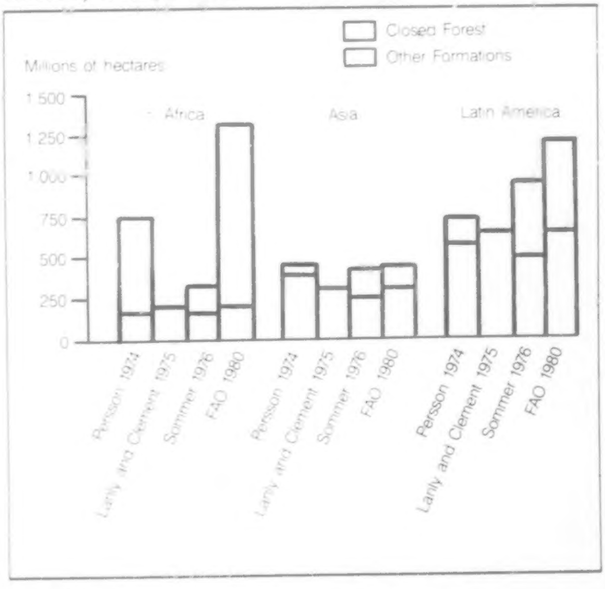
Unfortunately, scientists cannot pinpoint the extent of deforestation since the accuracy of assessments of global forest area over the past several decades has varied considerably (46). (See Figure 5.4.) In the early 1980s, average annual deforestation of open tree formations in tropical countries was estimated to be about 3.8 million hectares, though even this estimate includes only the area of forested land that is cleared and converted to non-forest uses, and doesn't take the effects of fuelwood collection, and other influences into account. (See Table 5.9.)

These uncertainties aside, the FAO has projected that 150 million hectares, or 12 percent, of the remaining closed tropical forests and roughly 76 million hectares of open tropical woodlands will be deforested by the year 2000 (47). Over the past ten years, 1.3 million hectares of closed broadleaved forests were cleared annually in Africa. Another 2.3 million hectares of open woodlands were also deforested each year in Africa between 1980 and 1985 (48). Much larger areas were degraded through harvesting for fuelwood and construction wood, cutting for fodder, grazing, fire, and drought. Conversion and degradation have been particularly severe in semi-arid West and East Africa, where supplies of fuelwood, poles, forage, and other secondary forest products that rural households need have dwindled. In all, African countries account for 62 percent of the deforestation of the world's open tropical forests and woodlands.

Over half of the forest loss (55 percent) occurred in the West African countries of Ivory Coast, Nigeria, Liberia, Guinea, and Ghana, where the rate of forest loss is seven times the world average. Each year, 290,000 hectares of closed forest in the Ivory Coast and 300,000 hectares in Nigeria are deforested. Annually, 50–100 million cubic meters of quality logs, or three to six times the annual production of sawlog and veneer logs in these countries, are lost through clearing and burning, along with wood that could be recovered and converted to charcoal or used as fuelwood (49). Most of the forest loss in East Africa is occurring in Madagascar, one of the richest tropical reservoirs of biological diversity. In Ethiopia, the forested area has shrunk from 16 percent of the land area in the 1950s to 4 percent in the 1970s, leaving the country increasingly vulnerable to droughts and floods.

In tropical Asia, 1.8 million hectares of closed forest were deforested every year between 1976 and 1980. Deforestation in this region results primarily from encroachment by lowland villages and shifting agriculture and from planned transmigration and resettlement. Especially large areas have been deforested in Indonesia, Thailand, Malaysia, Philippines, India, Burma, and Laos. Asia's highest rates of deforestation are in Nepal (3.9 percent) and Thailand (2.4 percent), where population size is large relative to the size of remaining closed forest areas. The forest area of the Himalayan watershed has declined by 40 percent over the past 30 years, contributing to shortages of food, fuel, and wood in the uplands and to floods and siltation in the lowlands.

Figure 5.4 Estimates of Tropical Forest Area in Africa, Asia, and Latin America



Sources:

1. Adapted from J.C. Allen and D.F. Barnes, "Deforestation, Wood Energy and Development" (Resources for the Future, Inc., unpublished, Washington, DC, 1982).
2. For 1974 estimates: R. Persson, *World Forest Resources: Review of the World's Forest Resources in the Early 1970s*, Research Notes No. 17 (Department of Forest Survey, Royal College of Forestry, Stockholm, 1974).
3. For 1975 estimates: J.P. Lanly and J. Clement, "Present and Future Natural Forest and Plantation Areas in the Tropics," *Unasylva*, Vol. 31, No. 123, pp. 12–20 (1979).
4. For 1976 estimates: A. Sommer, "Attempt at an Assessment of the World's Tropical Moist Forest," *Unasylva*, Vol. 28, Nos. 112 and 113, pp. 5–24 (1976).
5. For 1980 estimates: U.N. Food and Agriculture Organization (FAO), *Tropical Forest Resources*, FAO Forestry Paper No. 30 (FAO, Rome, 1982).

Table 5.9 Average Annual Deforestation of Tropical Forests by Forest Type and by Region, 1981–85[a]

(thousands of hectares)

Region	Productive Closed Forests: Undisturbed		Productive Closed Forests: Logged		Unproductive Closed Forests		All Closed Forests		Open Forests		Total Deforestation	
	Area	Percent[b]	Area	Percent[b]	Area	Percent[b]	Area	Percent[b]	Area	Percent[b]	Area	Percent[b]
Tropical America	1,299	(0.29)	1,867	(2.80)	1,173	(0.75)	4,339	(0.64)	1,272	(0.59)	5,611	(0.63)
Brazil	80	(0.03)	1,030	(8.58)	370	(0.65)	1,480	(0.41)	X	X	X	X
Tropical Africa	226	(0.19)	1,032	(2.41)	73	(0.14)	1,331	(0.61)	2,345	(0.48)	3,676	(0.52)
Zaire	155	(0.19)	25	(6.58)	2	(0.008)	182	(0.17)	X	X	X	X
Tropical Asia	395	(0.39)	1,278	(2.14)	153	(0.15)	1,826	(0.60)	190	(0.61)	2,016	(0.60)
Indonesia	X	X	600	(1.73)	X	X	600	(0.53)	X	X	X	X
Total	**1,920**	**(0.28)**	**4,177**	**(1.98)**	**1,399**	**(0.45)**	**7,496**	**(0.62)**	**3,807**	**(0.52)**	**11,303**	**(0.58)**

X = not available

Notes:

a. Tropical forest includes broadleaved, coniferous, and bamboo forests.

b. Calculated as percent of forest area in 1980.

Sources:

1. U.N. Food and Agriculture Organization (FAO), 1982, Reference 12.
2. U.S. Congress, Office of Technology Assessment, 1984, Reference 2.

Estimates of China's forested area vary widely. Land use data indicate that forest and woodlands increased in area from 115 to 128 million hectares between 1975 and 1982 (50). According to other FAO data, 170 million hectares were wooded in China in 1980, including 125 million hectares of closed forest and another 45 million hectares of other wooded land (51). However, despite the world's most ambitious reforestation program, it appears that fires, clearing for agriculture, uncontrolled cutting, and management failures have led to the loss of 16 million hectares of forests in five of China's most densely forested provinces since 1955. In Yunnan province, the forest cover declined from 55 percent to 30 percent of the land area between 1949 and 1975, a difference of 11 million hectares. Timber production in China has declined since 1979, and in 1972–77 some 35 million hectares of cropland (double the area affected in 1950–58) were subject to severe flooding or droughts (52).

While annual deforestation rates are predicted to level off in tropical Africa and Asia, rates were expected to increase in Latin America to over 4 million hectares per year in 1985 (53). From 1976 to 1980, 3.8 million hectares per year were cleared or converted to other uses. Apart from Brazil, which accounts for 35 percent of the annual deforestation of closed forests in tropical America, large areas are deforested each year in Peru, Venezuela, Bolivia, Colombia, Ecuador, and Mexico. Annual deforestation rates are especially high (greater than 3 percent) in Paraguay, Costa Rica, and El Salvador (54). In Haiti, the forest cover had already been reduced to less than 10 percent of the land area by 1978, though losses continue (55).

Deforestation in tropical America has been driven by population growth, pressure to clear more land for farming, land speculation, and the development of commercial ranches. Government fiscal policies also have a strong effect. For example, squatters in Amazonia can establish proprietary claims and increase the resale value of land by clearing the forest cover. Similarly, businesses can reduce their tax obligations by investing in ranches in Amazonia (56). In Brazil, deforestation may claim close to several million hectares per year. In six Amazonian states, the deforested area increased by more than 150 percent between 1975 and 1978 to 7.3 million hectares (57). Costa Rica was two-thirds forested as recently as 1940, and only one-third forested by 1980 (58).

In Table 5.10, tropical countries are grouped according to average annual deforestation rates and the area of closed forest cleared annually. In Group I, deforestation rates are relatively high and considerable areas are affected by forest loss. In Group II, the areas of closed forest area annually cleared in most countries exceed 20,000 hectares per year, though the deforestation rate is 0.5 percent per annum or lower. Deforestation in Group I and Group II countries represents 98 percent of annual losses to closed tropical forests. In Group III, the rate of deforestation is high (over 0.6 percent), but the area affected is small (less than 20,000 hectares). In Group IV, small areas are affected and deforestation rates are generally low.

RANGELAND RESOURCES

About one half of the earth's terrestrial surface is considered natural rangeland. It can occupy areas as diverse as the open forest of the southeastern United States, the grasslands of the Russian steppe and tundra, the deserts of the Mideast, and the sub-Saharan savanna and thorn scrub.

Strictly speaking, rangelands are wild forage-producing areas under native grasses used, among other things, for livestock, wildlife, and watershed maintenance. However, many analyses of range resources also refer to the FAO statistical category of permanant meadows and pastures, which includes more intensively managed areas (i.e., fenced, seeded, fertilized, and irrigated) that yield a controlled high productivity (such as hay fields).

Importance of Rangelands

More than one third of the earth's land area is too dry for rainfed agriculture and these arid zones constitute most of the world's rangelands. Of these, about 2.3 billion hectares (or half the arid and semi-arid lands) are in developing countries (59). At least half of these areas may be too rocky, steep, poorly drained, or cold to farm, but they do support grasses and other forage plants. This native forage, in turn, can support livestock that is grown

Table 5.10 Deforestation in Tropical Countries, 1981–85

Country	Closed Forest Area, 1980 (thousand hectares)	Annual Rate of Deforestation 1981–85 (percent)	Area Deforested Annually (thousand hectares)
Group I[a]			
Colombia	47351	1.7	820
Mexico	47840	1.2	595
Ecuador	14679	2.3	340
Paraguay	4100	4.6	190
Nicaragua	4508	2.7	121
Guatemala	4596	2.0	90
Honduras	3797	2.4	90
Costa Rica	1664	3.9	65
Panama	4204	0.9	36
Malaysia	21256	1.2	255
Thailand	10375	2.4	252
Lao People's Dem Rep	8520	1.2	100
Philippines	12510	0.7	91
Nepal	2128	3.9	84
Vietnam	10810	0.6	65
Sri Lanka	2782	2.1	58
Nigeria	7583	4.0	300
Ivory Coast	4907	5.9	290
Madagascar	12960	1.2	150
Liberia	2063	2.2	46
Angola	4471	1.0	44
Zambia	3390	1.2	40
Guinea	2072	1.7	36
Ghana	2471	0.9	22
Total	**241037**	**1.7**	**4180**
Group II[b]			
Brazil	396030	0.4	1480
Peru	70520	0.4	270
Venezuela	33075	0.4	125
Bolivia	44013	0.2	87
Indonesia	123235	0.5	600
India	72521	0.2	147
Burma	32101	0.3	105
Kampuchea, Dem	7616	0.3	25
Papua New Guinea	34447	0.1	22
Zaire	105975	0.2	182
Cameroon	18105	0.4	80
Congo	21508	0.1	22
Gabon	20690	0.1	15
Total	**979836**	**0.3**	**3160**
Group III[c]			
El Salvador	155	3.2	5
Jamaica	195	1.0	2
Haiti	58	3.4	2
Kenya	2605	0.7	19
Guinea-Bissau	664	2.6	17
Mozambique	1,189	0.8	10
Uganda	879	1.1	10
Brunei	325	2.2	7
Rwanda	412	0.7	3
Benin	47	2.1	1
Total	**6529**	**1.2**	**76**
Group IV[d]			
Belize	1385	0.6	9
Dominican Republic	685	0.6	4
Cuba	3025	0.1	2
Trinidad and Tobago	368	0.3	1
Bangladesh	2207	0.4	8
Pakistan	3785	0.2	7
Bhutan	2170	0.1	2
Tanzania	2658	0.4	10
Ethiopia	5332	0.2	8
Sierra Leone	798	0.8	6
Central African Republic	3595	0.1	5
Somalia	1650	0.2	4
Sudan	2532	0.2	4
Equatorial Guinea	1295	0.2	3
Togo	304	0.7	2
Total	**31789**	**0.2**	**75**

Notes:
a. Higher than average rate of deforestation and large areas deforested
b. Relatively low rates of deforestation but large areas deforested
c. High rates of deforestation and small areas of remaining forest
d. Low or moderate rates of deforestation and small areas affected

Sources:
1. U.N. Food and Agriculture Organization (FAO), 1981, Reference 44
2. FAO, 1981, Reference 49
3. FAO, *Los Recursos Forestales de la America Tropical* (FAO, Rome, 1981)
4. FAO/U.N. Economic Commission for Europe, 1985, Reference 10

for meat and other products and wildlife, which provides a reservoir of genetic diversity as well as a major source of protein and income in many developing countries.

The world's livestock herd amounts to more than 2.3 billion head of cattle and sheep, and over 700 million head of other types of livestock. Globally, the total investment in domestic livestock is on the order of $400 billion (60). In developing countries, livestock is a common means of accumulating capital. These assets can reproduce and are readily liquidated if cash is needed. Worldwide, exports of fresh and frozen meat, milk, wool, and live animals represented 12 percent of total agricultural exports in 1983. In many African countries livestock products account for more than half of total agricultural exports. (See Table 5.11.)

Although hay from tame pastures, feed grains, concentrates, and byproducts of milling and food processing now supply a significant fraction of livestock rations (61), forage from native rangelands and pasture still accounts for 80–85 percent of the feed of ruminant livestock (62); in developing countries, it supplies more than 95 percent of total feed. In the United States, native rangelands contribute about 16 percent of the feed of sheep and cattle, while pasture grazing provides 55 percent. The remaining 29 percent is supplied by feed grains and concentrates (63).

Rangelands support an estimated 30–40 million nomadic and pastoral people, including 16 percent of the population of Afghanistan and large numbers in Mauritania, Chad, Mali, Sudan, Somalia, Ethiopia, Kenya, India, and China (64). Many more, involved in animal husbandry, depend at least partly on rangelands. The economic contribution of pastoralists to national economies can be essential. For example, livestock products account for 67 percent of Somalia's agricultural exports, although nomads represent only 10 percent of the total population of the country.

In developing countries, livestock supplies half of the non-human energy used in agriculture, as well as dung needed to maintain soil fertility (65). Without livestock, developing countries would have to spend an additional $40 billion on mechanical power for agriculture and $6 billion on fertilizers. Draught animals are needed not only for plowing, but also for transportation and pumping of irrigation water. In both Asia and Africa, livestock is more important than tractors as a source of power on farms.

Rangelands are also sources of fuelwood, fencing materials, roof thatch, edible fruits and leaves, tannins, gums, and other products rural communities need. The wildlife that roams rangelands provides 50 percent of the

Table 5.11 Value of Livestock Products in Agricultural Exports, 1983

(billions of U.S. dollars)

Region	Meat Exports	Milk Exports	Live Animal Exports (Cattle, Sheep, Goats)	Wool Exports	Subtotal Livestock Exports	Total Agricultural Production Exports	Livestock Products as Percent of Total Agricultural Exports
Africa	0.1	—	0.6	0.2	0.9	10.9	8
Asia	0.8	0.07	0.4	0.05	1.3	27.5	5
South America	1.4	0.02	0.2	0.2	1.8	19.4	9
North America	1.8	0.40	0.4	—	2.6	56.3	5
Europe	8.9	3.60	2.1	0.1	14.8	80.2	18
Oceania	2.8	0.40	0.2	1.7	5.1	10.9	47
Total Developed Countries	13.4	4.90	2.5	2.0	22.5	141.8	16
Total Developing Countries	2.5	0.10	1.3	0.2	4.1	65.7	6
Total World	**15.9**	**4.60**	**2.8**	**2.6**	**25.6**	**207.5**	**12**

— = negligible value

Note: Numbers have been rounded to nearest 0.1 billion.

Source: Adapted from U.N. Food and Agriculture Organization (FAO), *FAO Trade Yearbook*, Vol. 37 (FAO, Rome, 1984).

meat consumed in Botswana and forms the basis of tourism, the second most important source of foreign exchange in Kenya.

Extent of Rangelands

There is no comprehensive global assessment of the extent of rangelands. Even defining "rangeland" is difficult. The term describes both land use and cover. The most complete data available—from the FAO—are organized by type of vegetation; thus, the total extent of rangeland must be calculated by adding parts of various FAO categories. The best available estimate for the world as a whole and for the major regions is presented in Table 5.12. It adds the area of permanent pasture, 3.16 billion hectares, to the 1.37 billion hectares of open forests and about half the FAO's "other land" category, 2.19 billion hectares of desert, tundra, and scrub. The total amount of rangelands by this estimate is 6.7 billion hectares or about 51 percent of the total land area of the world.

Condition of Rangelands

Range condition is an estimate of how close the range is to its natural potential cover, or climax vegetation, given a site's soil, rainfall, and other characteristics (66). Range condition is good if the forage production rate is 80 percent or more of site potential; poor if the forage production rate is 20 percent or less of site potential (67). The trend indicates whether the forage production rate is improving, deteriorating, or relatively stable.

Data on rangeland condition are sparse or non-existent for much of the world. A lack of standardization in classification and analysis compounds the problem. However, a number of national and sub-national studies conducted over the past ten years indicate conditions and trends in some key countries.

Xerification, or a drying of the soil, leads to the phenomenon called "desertification." Xerification most commonly results from overstocking, or overuse of a portion of the available forage by homogeneous herds of cattle, for example. It also results from use of rangeland for dry land agriculture. Heavy grazing by cattle selectively removes the most palatable perennial native grasses called "decreasers" and results in patches of bare soil, increases of less productive and nutritious annual grasses called "increasers" or invasion by foreign species called "exotics." Desertification also results in less litter and more compaction of the soil. Then the infrequent but heavy rains characteristic of arid zones do not have a chance to percolate into the soil, recharging underground aquifers and providing moisture to the plants. Instead, the rains carry the topsoil away.

Table 5.12 Distribution of the World's Pastures and Rangelands 1955–83

	Area of Permanent Pasture[a] (million hectares) 1955	1975	1983	Permanent Pasture As Percent of Land Area 1983	Open Forests[b] 1980 (million hectares)	Other Land[c] 1983 (million hectares)	Estimated Total Area Range and Pasture[d] (million hectares)	Rangeland As Percent of Total Land Area
North America (United States and Canada)	277	265	265	14	275	746	913	50
Europe	83	88	86	18	22	91	153	33
USSR	124	374	373	17	137	702	861	39
Central America (inclusive & Caribbean)	79	94	95	32	0.3	99	145	48
South America	330	446	456	26	248	230	819	47
Africa	615	785	778	26	508	1,317	1,945	65
Asia (except China)	279	372	359	21	61	602	721	41
China	194	286	286	31	45	415	538	58
Oceania	377	472	460	55	76	182	627	75
World Total[e]	**2,358**	**3,181**	**3,157**	**24**	**1,372**	**4,384**	**6,721**	**51**

Notes:

a. Includes permanent meadows and pastures, and land that has been used for five years or more for the production of herbaceous forage crops, either cultivated or wild.

b. Includes wooded land with a grass understory beneath the open canopy. Livestock and wildlife browse on both the leaves and twigs of the trees and on the grasses.

c. "Other land" is a residual category defined by the U.N. Food and Agriculture Organization (FAO) in its *Production Yearbook*. About one-third of this land is so dry it lacks plant cover. However, a significant percentage of this land may be grazed seasonally or in years of heavy rainfall. Half of this category is counted in the estimated total area of range and pasture.

d. Sum of areas of permanent pasture (1983), open forest (1980), and 50 percent of "other land" (1983).

e. Numbers may not add up to totals because of rounding.

Sources:

1. Data on "permanent pasture" and "other land" are from U.N. Food and Organization (FAO), *1983 Production Yearbook*, Vol. 38 (FAO, Rome, 1985), Table 1, pp. 47-48, and FAO, *1955 Production Yearbook* (FAO, Rome, 1955).
2. Data on open forests and other wooded land are from FAO, 1985, Reference 10.

Where grain cropping intrudes into rangelands, nutrients are lost at a rate 30 times that of a properly stocked range (69). In many areas, replacing lost phosphorous, potassium, and nitrogen with commercial fertilizers is far too costly, so that nutrient impoverishment contributes further to desertification.

In many desertification-prone countries, range development efforts have concentrated on raising productivity by improving animal health, developing new sources of water, introducing new breeds, or increasing the production of forage crops and intensively managed pastures. However, the lack of attention to the condition of the range itself, together with its increasing use, often results in large-scale deterioration.

Africa

In Africa, rangelands are concentrated in the Sahel in West Africa and in the countries bordering the semi-arid areas of East and South Africa. Seventy-five percent of Botswana is permanent pasture, and about 65 percent of Zambia, South Africa, and Lesotho is permanent pasture. Forty-five to 60 percent of the land area of Somalia, Mozambique, and Madagascar is considered native rangeland. Summaries of studies of nine African countries are shown in Table 5.13.

In the north African countries of Morocco, Tunisia, Algeria, Libya, and Egypt, forage production from rangelands has been declining, and overgrazing has caused the rangeland to deteriorate in many areas. However, a tropical rangeland often shows much higher recovery rates than those found in temperate zones. In Tunisia, temporarily protecting the range from grazing has increased forage production from 128 kilograms per hectare (kg/ha) to 1,244 kg/ha in just four years.

In Zambia, where livestock numbers are ten times greater than the carrying capacity of the available rangelands, the range is rapidly deteriorating. Large areas of Zimbabwe's rangelands are also overgrazed or bare, including 8 million hectares of former tribal trust lands.

Range conditions in the drier, northern part of Cameroon are generally poorer than in the wetter, southern Guinean zones, where livestock numbers are limited by trypanosomiasis. In the north, heavy overgrazing, frequent fires, and periodic droughts have caused annual grasses, unpalatable shrubs, or bare ground to replace the original perennial grasses and leguminous trees. A recent assessment of 36 range-management units indicated that 7 out of 16 units in the north were in poor or very poor condition, while 6 out of 13 units in the south were in excellent or good condition. The remaining 7 units were in fair condition (68). Dwindling productivity in northeastern Uganda's range also stems mainly from overstocking. Range resources in northern Kenya are reportedly in poor condition, although other ranges in the south are in fair condition. The condition of rangelands in both Sudan and Somalia is also reportedly deteriorating as unpalatable shrubs or annuals overtake perennials.

In the Sahel region of West Africa, the worst rangeland conditions are found near year-round water supplies and where pastoral and agricultural land uses overlap. (See Box 5.1.)

Of 19 countries in the Sudano-Sahelian zone, only Guinea and Guinea-Bissau report stable conditions; eight countries report some increase and nine report a significant increase in desertification. (See Part IV, "Forests and Rangelands," Table 6.3.)

Near East

Many ranges in the Near East are in poor condition. Unpalatable shrubs have invaded Iraq's steppe rangelands. In Syria's interior steppes and arid deserts, the original plant community has been replaced by species of little value to people or animals. Yemen's rangelands are in poor condition and deteriorating, and "erosion pavement" is now common in Jordan's rangelands. The alpine meadows of Iraq, where the harsh winters preclude year-round use, and the deserts and mountains of Oman, where herd sizes have been decreasing and the use of fodder crops increasing, are still in relatively good condition. In southern Saudi Arabia, the number of unpalatable species has recently increased, and 60 percent of all range management units are in poor or fair condition, compared to 40 percent in good or excellent conditon.

Rangeland condition in much of Afghanistan is fair or good, but declining as a result of overgrazing, especially around Kandahar and Herat and along the major migration routes. In Pakistan, most rangelands are in poor condition, producing only 10–15 percent of their potential and losing important species of palatable forage plants, including the woody *Acacia*. Iran's rangelands are already the most depleted in the region, and their condition is deteriorating.

Europe

Only 18 percent of Europe's land area is permanent pasture, but these lands receive adequate rainfall, are intensively managed, and are highly productive. The area of permanent pasture in Africa is six times greater than Europe's, but Europe supports 75 percent more cattle and sheep than Africa, and the value of Europe's livestock product exports is 16 times greater than Africa's. The productivity of Europe's pasturelands has increased beyond 500 animal production units (APU) per hectare per year, compared to less than 20 APU/hectare/year in most developing countries.

United States and Australia

Since 1936 the rangeland conditions in the United States have been regularly assessed. Overall conditions have gradually improved. For example, the area of nonfederal rangeland in excellent and good condition has increased from about 16–20 percent to a current level of 34–36 percent. (See Figure 5.5.)

Out of 347 million hectares of rangelands in the United States, roughly 207 million hectares (about 60 percent) are currently in good or fair condition. The remainder, some 40 percent, are in poor or very poor condition. Large areas of Alaskan rangeland, which are in good condition because they have not been exploited for long periods, tend to skew the national averages upward. For the lower 48 states, 46 percent of the rangelands are in

Table 5.13 Rangeland Conditions in Selected African Countries

Country/Locality	Size of Area	Range Condition	Range Trend	Causes
Cameroon				
Country-wide	8,300,000 hectares	Original perennial grassland and acacia types mostly replaced by annuals and unpalatable shrubs	Not specified, but potential for livestock development (based on forage yields) for 16 resource management units as follows: 3—very low; 4—low; 7—medium; 2—high or very high	Many years of heavy grazing and frequent burning
Northern Sector	7,000,000 hectares			Recent (about 1975) drought
Sudano-Sahel region (Acacia grasslands and steppes-Sahel; dry and moist woodlands—Sudanian types)		"Almost denuded state" in many areas		
Guinea-Congolian region (south of Garoua)		Range in better condition than Sudano-Sahelian types	Potential of 13 resource management units: 7—medium, 4—high; 2 very high	Use of range reosources limited by tsetse fly infestations
Southern Sector Adamaoua Plateau and other localized areas	About 1,300,000 hectares	Quality of range generally better than in northern sector	Not specified, but probably stable	More rainfall Tsetse fly limitations
Sudan	56,000,000 hectares ("permanent pasture") 24,000,000 hectares ("grasslands")	Range deteriorating and desertification accelerating	Apparently continuing downward	Increasing livestock numbers 5 to 18 million head cattle during last 30 years) Cultivation of marginal lands Woodcutting and uprooting of shrubs for fuelwood
Somalia	29,000,000 hectares	Overgrazed—perennial grasses replaced by annuals and in some cases by unpalatable shrubs	Deterioration accelerating	Overgrazing (increased demand for meat & livestock products)
Kenya Rendille management area (Northeast Kenya)	13,249 square kilometers	Based on field measurements of soil stability, composition plants species, percent bare ground and litter cover, state of soil erosion: Percent area of 22 management units: "Range" — "Woodland" (Browse) 2.4% Exc. 2.4% 1.5 Good 5.1 77.1 Fair 70.1 10.6 Poor 13.6 1.7 Very Poor 6.5 6.6 NA 2.2	Time trend data not available, but predominance of fair and poor condition indicates a serious state of rangeland degradation	Since some of the area had not been used for a long time due to tribal conflicts, the cause for the degraded condition is not certain; two hypotheses: — Previous excessive grazing completely suppressed preferred herbaceous plants, promoting growth of less desired species — Current vegetation is a climate climax type resultant from sporadic and low rainfall
Uganda Northeast region	5,000,000 hectares			
Entire Karamoia District	316,390 hectares	Perennial grasses replaced by plants with lower nutrient requirements, therefore less value as animal feed	Irreversible erosion	Majority of these Savanna grazing lands beyond zone of trypanosomiasis and livestock populations have increased rapidly during past decades (accounting for much of the country-wide increase)
Most of Acholi District	Semi-arid range	Reduction of ground cover Majority of grassland areas are four disclimax created by fire and grazing (and would return to dry forest if these factors eliminated)		Overgrazing (feeding and trampling)
Morocco	12,141,000 hectares rangelands, country-wide	Reduced forage production Expanding desertification	Deteriorating (e.g., degradation of Stipa Tenacissima "Alfa grassland" estimated at 10,000 hectares/year)	Overstocking Expanding dryland agriculture Uprooting of woody shrubs for fuel

Consequences/Projections	Remedial Activities	Source
	Northern Sector	
Severely degraded areas unlikely to recover without protection	Plans for protection/recovery of degraded rangelands include creation of controlled grazing reserves (320 potential areas already identified); the extremely degraded Chari Delta near Lake Chao and Diamare plain suggested as pilot areas	1
Pressure on open area grazing lands can be partially alleviated with tsetse control programs or livestock prophylaxis	Reseeding and water development efforts, combined with rotational grazing systems, proposed to mitigate range destruction around the limited number of dry season waterholes	
	Southern Sector	
Cattle increasing at 1-2% per year, but increase expected to cause forage degradation except around human population centers	Pilot project for livestock management in tsetse areas planned for locality south of Benoue River	
A total of 75-80 million hectares (ha) considered suitable for agriculture, but only 24 million ha currently used for grazing, 7 million used for farming	Not specified	2
The rangeland is the greatest natural resource of the country	A 1975 FAO/UNDP project to initiate range management education in the university was successfully established, but was terminated once project assistance ended Currently foreign aided range development program in operation	3
It is projected that significant improvements can be realized	Detailed and adaptive management plan, including grazing pressure and distribution recommendations, animal husbandry and disease control improvements, and development of a viable marketing system	4
Erosion	Few studies examining the extent of devegetation caused by livestock Problems have not been addressed sufficiently by the administration Improved pasture management research conducted by veterinary trainers at Entebbe (primarily for dairy cattle)	5
Increased soil erosion Decline in natural grassland area Increases in animal production only possible at the additional deterioration of range forage	Planting of forage shrubs: — Opuntia cactus, plantations can yield 10-50 metric tons green matter/hectares/year — Saltbush (Atriplex) New management practices including: — Control of grazing pressures — Rotation and deferred grazing schemes Houz afforestation project to protect soils and improve pasture	6

(continued on next page)

good or fair condition, with only 15 percent in good condition. Rangeland types in relatively poor condition include desert and annual grasslands, Texas savanna, southwestern shrub-steppe, and chapparal-mountain shrub.

In Australia, as in the United States, rangelands that were degraded in 1900 have gradually improved in recent decades in most areas. Overstocking, especially during dry periods, and the explosive growth in the population of introduced rabbits contributed significantly to the earlier degradation of Australia's rangelands. Currently, some 13 percent of all rangeland is affected by soil erosion and the degradation of natural vegetation.

DEVELOPMENT ASSISTANCE AND RANGE MANAGEMENT

The impacts of large-scale, international development assistance projects on tropical rangelands warrant close examination. Aid projects have generally attempted to raise the economic productivity of range use systems by promoting the use of homogeneous herds of cattle. Cattle can be marketed, and exported, in order to generate the foreign exchange needed to service external debt. However, large herds of cattle are not always well-suited to tropical range environments.

Confronted with a daunting record of failure in range management projects, assistance agencies are now taking a new look at the traditional pastoralist systems. Instead of large homogeneous herds, pastoralists generally graze small mixed herds that make use of the full spectrum of available vegetation. Camels eat the higher strata of woody vegetation, goats eat the lower strata, sheep consume herbaceous plants and grasses and can be selective with their prehensile lips; cattle are less selective grazers.

Moreover, pastoralists generally sell off the sick and weak animals, in contrast to western tradition. The very large herds, encouraged by assistance projects, overstress the ecosystem. When drought strikes, the entire system can collapse. When that happens, there is a longer term effect because of the disparity between the amount of time it takes for cattle herds to rebound and the amount of time required for rangelands to recover: cattle can be restocked within a few years, but it takes much longer to rejuvenate degraded rangeland, especially when soil—which forms at the snail's rate of one inch per 500 years—is eroded.

Range specialists identify the key underlying causes of these well-intentioned but repeated failures as the export of inappropriate technology and a remarkable failure to view the range community of plants, animals, and people as an integrated system. Until these failings are corrected, the sorry record of assistance-aided range "disasters" will likely continue.

THE DIFFICULTIES OF RANGE ASSESSMENTS

National-level evaluations of rangeland conditions often obscure important local variations (e.g., over 40 million hectares of U.S. range are in very poor condition although

Table 5.13 Rangeland Conditions in Selected African Countries

Country/Locality	Size of Area	Range Condition	Range Trend	Causes
Morocco				
Tunisia	3,142,000 hectares	Degraded Rangelands estimated to be producing at 1/2 of potential (optimistic estimate)	Presumed to be continually deteriorating	Uncontrolled grazing; fuelwood cutting Long history of misuse—traditional nomadism has been disrupted since colonial times (10 years) and the emphasis on sedentarization has concentrated grazing pressure Stocking rates estimated to 3–8 times higher than ideal
Zambia				
Country-wide Upper Zambezi (Western Province) Kafue River locality Eastern Province	35,000,000 hectares	Deteriorated; severe cover depletion	Not specified, but in view of excessive (tenfold) stocking rates, trend presumed down	Overgrazing—average stocking rate for entire country is 0.32–0.45 hectare/livestock unit (10–15 times higher than recommended) Surveys show rangeland degradation from overgrazing not perceived as a problem by rural inhabitants
Zimbabwe				
Tribal Trust Lands	16,161,000 hectares	Approximately 50 percent of this area in very poor condition (based on 1960 survey)	Most recent survey made in 1960; situation has certainly deteriorated	Overgrazing from increased livestock population (+119 percent 1964–77)
Buffalo Ranch Farm	20,000 hectares			Stocking rate management:
— Cattle section	12,000 hectares	Good condition (37.8% cover; 30% litter; 28% utilization)	Apparently stable, possibly improving	— 8.5 hectares/livestock unit
— Game section	8,000 hectares	Fair condition (30% cover; 20% litter; 43% utilization)	Apparently stable	— 8.0 hectares/livestock unit equivalent (455 kg)

Sources:

1. U.N. Food and Agriculture Organization (FAO), *1983 Production Yearbook*, Vol. 37 (FAO, Rome, 1984); and University of Arizona, *Draft Environmental Profile on United Republic of Cameroon* (Office of Arid Lands Studies, University of Arizona, Tucson, 1981), pp. 21–28, 32–35, and 47–48.
2. Op. cit. 1, FAO, and A.W. A. El Moursi, *Ecological Management of Arid and Semi-Arid Rangelands* (EMASAR—Phase II), Vol. VII, Near East (FAO, Rome, 1978), pp. 29–31; FAO, "Regional Study on Rainfed Agriculture and Agro-Climatic Inventory of Eleven Countries in the Near East Region," in *World Soil Resources Report* (FAO, Rome, 1982).
3. Op. cit. 2, El Moursi, pp. 23–24.
4. United Nations Education, Scientific and Cultural Organization (UNESCO), *Integrated Resource Assessment and Management Plan for Western District, Marsabit, Kenya*, IPAL Technical Report No. A-6, Part I and II (UNESCO, W.J. Lusigi, Ed., Paris, 1984).
5. Op. cit. 1, FAO; and U.S. Man and the Biosphere (USMAB), *Draft Environmental Profile of Uganda* (Office of Arid Land Studies, University of Arizona, Tucson, 1982), pp. 36, 48–52, 85–87, 92, and 122–123.
6. U.S. Man and the Biosphere (USMAB), *Draft Environmental Report on Morocco* (Office of Arid Lands Studies, University of Arizona, revised, Tucson, 1981), pp. 11–18.
7. Op. cit. 1, FAO; and University of Arizona, *Draft Environmental Profile on Tunisia* (Office of Arid Lands Studies, University of Arizona, Tucson, 1980), pp. 13–14, 16–18, 25, 33–34.
8. Op. cit. 1, FAO; and University of Arizona, *Draft Environmental Profile of Zambia* (Office of Arid Lands Studies, University of Arizona, Tucson, 1982), pp. iii, 70–71 and 97–102.
9. University of Arizona, *Draft Environmental Profile of Zimbabwe* (Office of Land Studies, University of Arizona, Tucson, 1982), pp. iii, 48–51, 55–64, 89–95.

overall, its condition is fair to good). However, they do reveal that areas of critical concern are found on many continents and in many biogeographic realms, at both high and low altitudes, and not surprisingly, are concentrated in countries heavily dependent on this resource for their economic well-being.

Of the 32 countries or regions analyzed in Figure 5.6, 14 are faced with such critically deteriorating range conditions that they fall within the high risk category; 9 areas (including the lower 48 states of the United States) are in the moderate risk category; and 9 (including Alaska) are in the low risk category.

No single cause can be found for the problems of countries whose range resources are at risk. Great differences in culture, climate, ecology, and economics make this resource a particularly site-specific challenge to manage. More than for most resource systems, data are less readily extrapolated from region to region and solutions found to work in one area may not work in another. Research is badly needed to develop a series of well defined management strategies that could prove more widely applicable than current approaches.

RECENT DEVELOPMENTS

INVESTMENT IN FORESTRY: PRIORITIES AND NEEDS

Over the past decade, less than 1 percent of the assistance provided by the international development banks has been allocated to forestry. (See Table 5.14.) Similarly, only 5 percent of the budget of the FAO is allocated to its Forestry Division (70). Although it increased in the late 1970s and early 1980s, investment in forestry in develop-

Consequences/Projections	Remedial Activities	Source
	Dakahala pasture improvement (beginning with tree shelter-belts later to plant shrubs suitable for grazing) 72,000 hectares area 1948–68, combined with forage planting Establish national seed production center (200 ha) Establish national committee for pasture land (planning to develop 25,000 ha grazing land each year)	
Traditional nomadism allowed periods for plant regrowth Forage production in a protected plot increased from 128 kg/ha after 1 year to 1,244 kg/ha after 4 years (including a good rainy year)	1958 law limiting goat raising 1960 and 1966 laws regulating exploitation of esparto grass (used for both paper and grazing) — Other range management activities not specified	7
Soil erosion widespread	Not specified and figures on the magnitude of the problem not readily available	8
Seriously deteriorated forage resource base	Some successful range management schemes introduced at a local level (details and locations not provided)	9
Severe droughts have caused high annual mortality in some areas, decreasing grazing pressure and allowing range to recover some	None required	
Assumed sustainable production	None required	
Assumed sustainable production		

ing countries still does not reflect forests' crucial role in sustaining food production, creating employment and income, providing essential raw materials and goods, and generating scarce foreign exchange.

For many reasons, forests in many developing and developed countries are now stressed, and policy changes and increased investment are needed urgently to head off serious productivity declines. Fortunately, given these needs, numerous recent developments in forestry offer encouragement.

Since 1982, the FAO has been preparing an action program for tropical forests. The detailed five-part action program covers fuelwood and wood energy, land use, forest industrial development, conservation of tropical forest ecosystems, and institution strengthening. Simultaneously, a task force convened in 1984 by the World Resources Institute (WRI), in cooperation with the World Bank and the United Nations Development Program (UNEP) reviewed the causes and remedies of low levels of investment in forest conservation and development in *Tropical Forests: A Call for Action* (71). The task force concluded that many proven responses to land misuse and deforestation exist and that the lack of political and, consequently, financial will to support them stems from a poor understanding of the consequences of failing to act. According to WRI, an estimated $8 billion in public and private investment is needed between 1987 and 1991. Half that amount could be provided by doubling development assistance, with the remainder provided by national governments and the private sector. The proposed action plan spells out a five-year investment program and includes case studies of successful projects models and specific investment profiles for 56 countries.

There has been a recent surge of activity among nongovernmental organizations (NGOs) engaged in forestry-related activities (72). A 1981 directory of 1,720 NGOs active in development assistance lists only seven engaged in forestry (73). Since then, afforestation projects have proliferated, not just in forestry programs, but in those to combat desertification, erosion, siltation, fuelwood shortages, and rural hunger.

Nationally, the thrust and impact of NGO activities defy generalization, though several examples illustrate the spectrum of efforts. In Haiti, dozens of local NGOs participating in a reforestation program coordinated through three U.S.-based international NGOs, and funded by the United States Agency for International Development (AID) have planted more than 10 million seedlings since 1981. In India, the number of village tree-planting groups has been estimated to exceed 40,000. In Indonesia, Senegal, and some other countries, NGOs involved in forestry and other resource conservation and development projects are so numerous that national consortia have been organized to facilitate coordination and communication among members. The Kenya Energy Non-Governmental Organization (KENGO) has 50 organizational members and 120 other associated private voluntary agencies. Such groups help produce and distribute seedlings, increase village-level participation, and push for legislative reform—key elements in successful reforestation programs.

INTERNATIONAL TROPICAL TIMBER AGREEMENT

After nine years of negotiations, an international agreement on the production and use of industrial wood from tropical countries was adopted in 1983 and ratified in March 1985 by the U.N. Conference on Tropical Timber, organized under the auspices of the U.N. Conference on Trade and Development (UNCTAD). Known as the International Tropical Timber Agreement (ITTA), its objectives are to promote international trade in industrial wood from tropical countries and to help tropical timber-producing and timber-consuming countries cooperate to allow management of tropical forests. In addition to regulating trade in tropical timber, ITTA also encourages research and development in five areas: improved forest management and wood utilization, further processing of tropical timber in producer countries, expanded reforestation and forest management, improved marketing and distribution of tropical timber exports, and increased study of trading patterns in tropical timber. No action under this new agreement has yet been taken.

Box 5.1 Primary Production in the Sahel—Implications for Range Resource Management

Ecological studies conducted between 1976 and 1981 by the "Institut d'Economie Rural" (Bamako, Mali) and the Dutch Government provide perhaps the best scientific basis for understanding the biophysical processes involved in Sahelian range forage production, the impacts of different intensities of exploitation, and the possibility of increasing forage yields. Many of the findings of this investigation are radically different from earlier understandings, and suggest a new interpretation of range management options for the Sahel. Key findings of the Primary Production in the Sahel (PPS) study (1) are:

■ The productivity of the Sahelian animal husbandry system, expressed in animal protein per unit area, is at least equal to, or even better than, that of ranching at comparable zones (100–600 mm rainfall) in the United States and Australia.

■ Even though nomadic and semi-nomadic pastoralists cope with their adverse environmental conditions extremely well (in terms of animal protein produced per unit area), production is often not sufficient to provide a subsistence level livelihood. Moreover, this production requires a mode of exhaustive exploitation that leads to deterioration of the environment, and thus cannot be maintained over the long-term. Animal husbandry in the Sahel needs to be rehabilitated.

■ In addition to decades of cash crop production in the Sahelian countries, the food requirements of the growing human population have caused an expansion of the agricultural crop area, increased intensity in land use (e.g., shortened fallow periods), and increased grazing pressure. These factors are causing a gradual decline in soil fertility and productivity.

■ On average, only 75 percent of the rainfall infiltrates the soil; the remainder runs off. (This runoff is an important source of surface drinking water.) Overexploitation of the pasture promotes excessive runoff and results in degradation of the environment.

■ In general, however, the Sahara is not advancing southward; a shortage of drinking water protects this desert border area against overexploitation. On the other hand, overexploitation is causing increasing degradation in the southern Sahel region and northern savanna areas (the Sudano-Sahelian interface zone where mixed farming is predominant).

■ Poor soil quality, both chemically and physically, is a great barrier to development. Precipitation is not used in an optimal way for plant production in the Sahel since the soils are deficient in both nitrogen and phosphorus. As a consequence, in the southern Sahel, for example, only 10 percent of the annual rainfall is used by the vegetation.

■ Fertilizers could increase primary production under natural rainfall as much as fivefold. However, the cost of nitrogenous fertilizers is not economic under the Sahelian animal husbandry system, nor are the treated phosphates (the rock phosphates available in some of the countries are absorbed 10–20 times more slowly by plants than are the super phosphates).

■ There are many indigenous legume species in the Sahel with good nitrogen-fixing capacity, but their ability to compete against grasses, their germination strategy, the low phosphorus status of the soils, and the low rainfall limit their contribution to the productivity and quality of the pastures. The only way to improve the growth of legumes in natural rangeland is by the application of phosphates. In the Sahel region proper, the cost of this measure could be five times greater than the value of the yield. Large-scale introductions of exotic legumes are unlikely to succeed, although experimentation with species requiring less phosphorus may be warranted.

■ Because of their favorable effect on the quantity and quality of available forage, fire and grazing are indispensable in the traditional pastoral grazing system. Attempts to combat degradation and decreases in productivity by banning fires and overgrazing can be successful only if solutions are found for the shortage of proteins in the forage during the dry season.

■ Dryland farming in the southern Sahel and northern Sudanian savanna profits more from animal husbandry than the animals do from the crop residues under current conditions. Benefits to the animals from increased integration of these activities can be realized only if the quantity and quality of the agricultural by-products are improved by fertilization.

■ The natural tree cover in the Sahel varies from 0–5 percent and is in balance with the water resources. Accordingly, afforestation has little chance of succeeding except in places where water runoff concentrates.

■ Technical options exist to increase productivity in the Sahel, although they are not economically feasible under present conditions. Hence, to increase, or even maintain, the productivity of the Sahel, external funding is necesary. Millions of dollars can, however, be spent more effectively if the ecological constraints on development are better understood and incorporated into the formulation and implementation of aid programs.

■ The study's results do not make it easier to formulate proposals for the accelerated development of the Sahel region. The soil is being depleted for both arable farming and animal husbandry. In many areas this is unavoidable and there is probably no alternative. Social and economic conditions in the region are such that modern methods of production (such as the use of fertilizer) are unlikely to succeed in the short term, and even if the situation were to change, environmental constraints preclude agricultural expansion on a large scale.

■ In spite of this bleak picture, the search for new ways to promote development is vital to the Sahel. The *status quo* means continued deterioration of the environment. In some cases, it may be justified to consider investments, which from a purely economic viewpoint produce no immediate returns. These could include such measures as the creation of alternative employment opportunities and improving regional infrastructure. Subsidizing meat and grain production would have negative internal rates of return, but could improve production. Possible programs might include:

1. Growing leguminous crops with the use of phosphorous fertilizers.
2. Continued integration of dryland farming and animal husbandry, combining the use of manure and chemical fertilizers to produce better quality forage.
3. Fattening operations on a small scale in situations where fertilizers can be used economically to produce such cash crops as cotton and groundnuts with high quality by-products.

References

1. H. Breman and P.W.J. Uithol, *The Primary Production in the Sahel (PPS) Project: A Bird's Eye View* (Center for Agrobiological Research, Wageningen, The Netherlands, 1984), pp. 5–8 and 37–41.

CHANGING PRIORITIES IN FORESTRY RESEARCH

The 1981 Congress of the International Union of Forestry Research Organizations (IUFRO) highlighted the need for increased support of forestry research related to Third World needs (74). Since then, the priorities of forestry researchers around the world have changed dramatically. The recommendations of a recent workshop on forestry research priorities in the Asian region stressed the importance of increasing the productivity of multipurpose tree species, increasing fuelwood supplies, rehabilitating and protecting watersheds and degraded lands, and generating income and employment through forestry (75). Future IUFRO workshops will cover related issues. In 1986, a second workshop in Africa will concentrate on the research needs of the Sahel and northern Sudanian zones. Participants will examine agroforestry, natural regeneration and forest management, the selection and improvement of multipurpose tree and shrub species, the use of nitrogen-fixing woody plants, and other low-input technologies to maintain soil productivity. A third workshop in Latin America will focus on more efficient harvesting, processing, and treatment of tropical woods.

Table 5.14 Distribution of Loans by International Development Banks, 1983

(millions of U.S. dollars)

Institution	Total Annual Lending[a]	Agriculture Sector[b]	Percent of Total	Energy Sector[c]	Percent of Total	Forestry Sector[d]	Percent of Total
The World Bank	14.477	3.698	26	2.818	20	83	0.60
Inter-American Bank	3.045	489	16	968	32	2	0.06
Asian Development Bank	1.893	825	44	524	28	52	2.70
African Development Bank	930	261	28	274	30	6	0.70
Totals	**20,345**	**5,273**	**26**	**4,584**	**22**	**143**	**0.69**

Notes:

a. Data are from 1983 Annual Reports for each agency and include loans authorized for all sectors: agriculture, forestry, industry, health, education, transportation, urban development, public utilities and energy.
b. Agriculture includes agriculture credit and rural development, agricultural research, as well as fisheries, livestock, and forestry.
c. Generally includes loans for oil, gas, coal, and power development; data for public utilities are substituted in the case of the African Development Bank, which did not report on a separate category for energy projects.
d. Does not include capital investment in pulp and paper industrial processing capacity. Data are from bank reports and personal communications.

Sources:

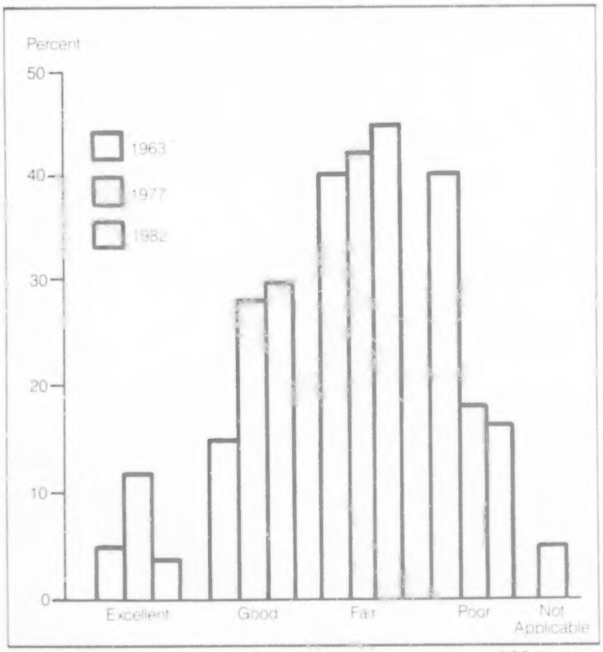
1. The World Bank, *The World Bank Annual Report 1983* (The World Bank, Washington, D.C., 1983).
2. Inter-American Development Bank, *Annual Report 1983* (Inter-American Development Bank, Washington, D.C., 1983).
3. Asian Development Bank, *Annual Report 1983* (Asian Development Bank, Manila, 1983).
4. African Development Bank, *Annual Report 1983* (African Development Bank, Abidjan, Ivory Coast, 1983).

The main themes of the 1986 IUFRO World Congress are multipurpose tree species, utilization of tropical woods and related topics, air pollution's effects on forests, wood for energy, and forest resource monitoring.

Two major research efforts devoted solely to agroforestry are also under way. The International Council for Research in Agroforestry is completing a global inventory of agroforestry systems, especially in traditional land use systems in developing countries. In addition, FAO has helped establish networks of research institutions aimed at increasing knowledge and use of forest trees, food trees, and fruit-bearing species.

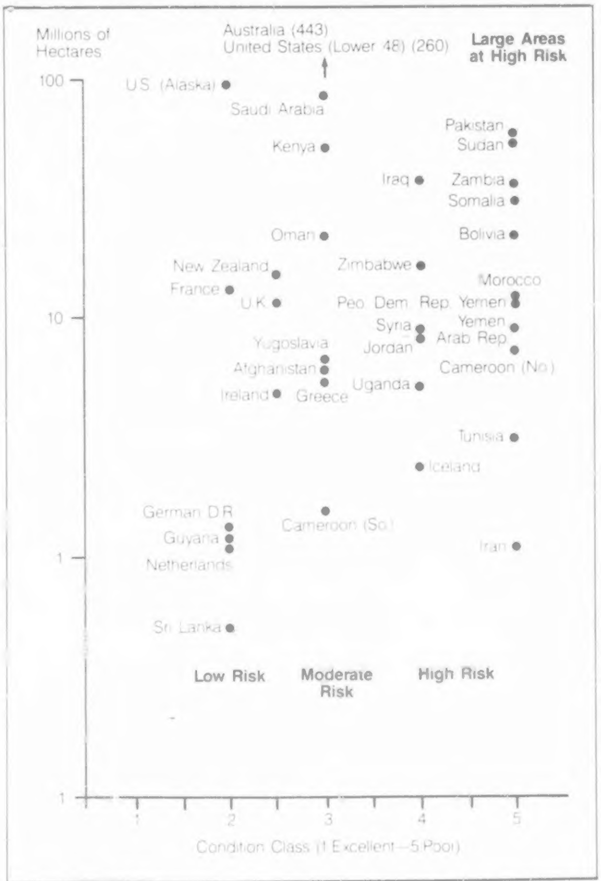
Several new journals reflect the shift to new areas of emphasis in forestry. They include the *Agroforestry Systems Journal*; the *Journal of Agriculture, Ecosystems and Environment*; and *The International Tree Crops Journal*. *New Forests*, an international journal on the biology, biotechnology, and management of afforestation and reforestation, will begin publication in 1986.

Figure 5.5 Distribution of U.S. Nonfederal Rangeland by Condition Class, 1963, 1977, and 1982



Source: Soil Conservation Service (SCS), *1985 RCA Appraisal Update* (SCS, Washington, DC, draft 1985), p. 71.

Figure 5.6 Global Sample of Rangeland Extent and Condition



Note: The high percentage of tame pasture rather than rangeland *(sensu stricto)* in European countries accounts for their very high productivity (i.e. twenty times USSR and USA) and condition.

Source: Compiled by World Resources Institute from various sources.

References and Notes

1. U.S. Forest Service, *An Assessment of the Forest and Range Land Situation in the U.S.* (U.S. Department of Agriculture, Washington, D.C., 1980), p. 25. Rangeland is land having less than 10 percent cover of forest trees, on which the existing or potential natural vegetation is predominantly grasses, grass-like plants, forbs, or shrubs. Others have defined rangeland more broadly, to include all land producing native forage for animal consumption; such land is generally too dry, steep, rocky, wet, or otherwise limited for most intensive cropping uses. The second, broader definition would include land that is also classed as "open forest."
2. U.S. Congress Office of Technology Assessment, *Technologies to Sustain Tropical Forest Resources* (U.S. Congress, Washington, D.C., 1984), p. 65. *Forest area* generally includes both closed and open forests. *Closed forest* has a cover of trees sufficiently dense to prevent the development of a grass understory. *Open forest* has at least 10 percent tree cover, but enough light penetrates the tree canopy to permit the growth of grass under the trees.

   In addition to closed and open forests, *wooded land* may also include forest fallow, shrubland, and the estimated area covered by trees outside the forests. *Forest fallow* is land that has been cleared and used for shifting cultivation within the last 20 years and now supports a regrowth of woody plants. *Shrubland* has a vegetative cover dominated by shrubs (woody plants less than 7 meters high) because of either low rainfall or degradation of the tree cover.
3. R. Winterbottom, *Rwanda Integrated Forestry and Livestock Project*, Report of the Phase II Rural Forestry Preparation Mission (Food and Agriculture Organization/World Bank, Washington, D.C., 1985), p. 6.
4. B. van Gelder and P. Kerhof, *The Agroforestry Survey in Kakamega District*, Final Report, Kenya Woodfuels Development Program (KWDP) Working Paper No. 6 (KWDP, Nairobi, 1985), pp. 14–15.
5. People's Republic of China, Ministry of Forestry, *China's Forestry and Its Role in Social Development* (Ministry of Forestry, presented, World Forestry Congress, Mexico City, 1985), p. 28.
6. Economic Commission for Europe (ECE)/Food and Agriculture Organization *The Forest Resources of the ECE Region* (ECE, Geneva, 1985), Table 1.2, pp. 16–18.
7. P. Buringh, in *The World Environment 1972-1982* (M.W. Holdgate, *et al.*, Eds. United Nations Environment Program, Dublin, 1982), p. 253.
8. J.S. Olson, "Productivity of Forest Ecosystems," in *Productivity of World Ecosystems* (National Academy of Sciences, Washington, D.C., 1975), p. 41.
9. *Op. cit.* 2, p. 65. Broadleaved forests are also referred to by the "hardwood" they produce, as opposed to the "softwoods" produced in coniferous or needle-leaved forests.
10. U.N. Food and Agriculture Organization (FAO)/Economic Commission for Europe (ECE), *Forest Resources 1980* (FAO/ECE, Rome, 1985).
11. U.N. Food and Agriculture Organization (FAO), "Forestry Beyond 2000," *Unasylva*, Vol. 37, No. 147, p. 12 (1985).
12. U.N. Food and Agriculture Organization (FAO), *Tropical Forest Resources*, Forestry Paper No. 30 (FAO, Rome, 1982), Table 1f, p. 50.
13. U.N. Food and Agriculture Organization (FAO), *1983 Production Yearbook*, Vol. 37 (FAO, Rome, 1984), Table 1, p. 56.
14. *Ibid.*
15. *Op. cit.* 12, p. 50.
16. E. Matthews, "Global Vegetation and Land Use," *Journal of Climate and Applied Meteorology*, Vol. 22, pp. 474–487 (1983).
17. U.N. Food and Agriculture Organization (FAO), *Production Yearbooks*; 1950–82 (FAO, Rome, 1950–82), Table 1.
18. The net forest products import bill for the ten states of the European Economic Community increased from $9 billion to $17.5 billion between 1974 and 1980, when it represented the second largest expenditure of foreign exchange after oil.
19. F.C. Hummel, "In the Forests of the EEC," *Unasylva*, Vol. 34, No. 138, pp. 2–16 (1982).
20. *Op. cit.* 1, pp. 28–31; and Food and Agriculture Organization "Wood: World Trends and Prospects," *Unasylva*, Vol. 20, No. 80–81, Table III–A, p. 66 (1966).
21. *Op. cit.* 2, p. 65. "Unproductive" refers to forests that cannot be exploited commercially because of accessibility, topography, or other reasons. Such forests may be highly productive in an ecological sense. In the United States, such forests are termed "non-commercial."
22. *Op. cit.* 12, pp. 80 and 84.
23. J. Melillo, *et al.*, "Comparison of Two Recent Estimates of Disturbance in Tropical Forests," *Environment Conservation*, Vol. 12, No. 1, pp. 37–40 (1985).
24. *Op. cit.* 6, Table 1.3, pp. 19–20.
25. *Op. cit.* 12, pp. 12, 47, and 50. "Productive" closed forests are those in which the production of wood for industry (sawlogs, pulpwood, and other industrial wood) is possible.
26. *Op. cit.* 12, p. 47.
27. *Op. cit.* 7, p. 253.
28. U.N. Food and Agriculture Organization, "Wood: World Trends and Prospects," *Unasylva*, Vol. 20, No. 80–81, Table III–A, p. 66 (1966).
29. *Op. cit.* 12, pp. 12–13. Applicable in the case of closed productive forests that have been or will be commercially logged, the term implies that harvesting is regulated and followed by silvicultural and protection measures designed to maintain commercial productivity.
30. *Op. cit.* 10. Eighty-eight percent of the publicly owned forests have management plans, as opposed to 27 percent of the 72.5 million hectares of privately owned closed forest land in Europe. However, uses are controlled for most of the remainder of private forest lands.
31. *Op. cit.* 12, pp. 47 and 56–58.
32. *Op. cit.* 12, p. 47.
33. World Resources Institute (WRI), "Forest Management for Industrial Uses," Tropical Forests Action Plan Project (WRI, paper, Washington, D.C., 1985), pp. 23–26.
34. United Nations Environment Program (UNEP), *The World Environment 1972–1982*, M. Holdgate, *et al.*, Eds., (UNEP, Dublin, 1982), p. 234.
35. World Resources Institute, *Tropical Forests: A Call for Action*, Part I (WRI, Washington, D.C., 1985), pp. 37–38.
36. International Union for Conservation of Nature and Natural Resources (IUCN), *The United Nations List of National Parks and Protected Areas* (IUCN, Gland, Switzerland, and Cambridge, U.K., 1985).
37. *Op. cit.* 1, p. 31.
38. *Op. cit.* 6, Table 1.3., pp. 14–15. Does not include privately owned and locally protected areas.
39. *Op. cit.* 6, Table 1.4, pp. 21–22.
40. *Op. cit.* 10; and P. Wardle, Food and Agriculture Organization, Rome, 1985 (personal communication). Reforestation includes some areas of managed "natural" regeneration, reforestation of recently harvested or cleared land, and afforestation of land which has not supported a forest cover in the recent past. In most cases the area "reforested" or planted includes an unknown area of failed plantation that must be replanted in succeeding years.
41. U.N. Food and Agriculture Organization (FAO), *Yearbook of Forest Products 1972–1983* (FAO, Rome, 1985), pp. 14–15. Available statistics on wood "production" are equivalent to wood removals (amount of wood harvested) and to wood consumption but do not represent the annual increment or measured growth of trees and forests. Total roundwood production is the sum of all wood removed from forests and trees outside the forests, including fuelwood, industrial wood, and the equivalent roundwood volume of wood converted into charcoal and chips.
42. World Bank, "Economic Analysis Issues in Bank Financed Forestry Projects" (World Bank, AGR technical note, draft, November 1984), p. 54.
43. K. Newcombe, "An Economic Justification for Rural Afforestation: The Case of Ethiopia," Energy Department Paper No. 16 (World Bank, Washington, D.C., 1984), p. 16.
44. U.N. Food and Agriculture Organization (FAO), *Forest Resources of Tropical Asia* (FAO, Rome, 1981), p. 59.
45. *Op. cit.* 5, pp. 27–30.
46. J. Allen and D. Barnes, "Deforestation, Wood Energy and Development" (Resources for the Future, paper, Washington, D.C.) pp. 5–6.
47. *Op. cit.* 12, p. 101.

48. *Op. cit.* 12, p. 84.
49. U.N. Food and Agriculture Organization (FAO)/United Nations Environment Program, *Forest Resources of Tropical Africa*, Part I (FAO, Rome, 1981), pp. 83–90.
50. *Op. cit.* 13, Table 1, p. 50.
51. *Op. cit.* 10.
52. V. Smil, "Deforestation in China," *AMBIO*, Vol. 12, No. 5, pp. 226–231 (1983).
53. *Op. cit.* 12, p. 77.
54. *Op. cit.* 12, p. 80.
55. L. Lewis and W. Coffey, "The Continuing Deforestation of Haiti," *AMBIO*, Vol. 14, No. 3, pp. 158–160 (1985).
56. P.M. Fearnside, "Human Use Systems and the Causes of Deforestation in the Brazilian Amazon," (U.N. University Conference on Climatic, Biotic and Human Interactions in the Human Tropics, presented, Sao Paulo, Brazil, February 1985), Table 1, p. 22.
57. Tucker, *et al.*, "Intensive Forest Clearing in Rondonia, Brazil, as Detected by Satellite Remote Sensing," *Remote Sensing of Environment*, Vol. 15, pp. 255–261 (1984).
58. S. Sader and A. Joyce, *Global Tropical Forest Monitoring* (unpublished paper, 1985).
59. U.N. Food and Agriculture Organization (FAO), *State of Food and Agriculture 1982* (FAO, Rome, 1983), p. 127. The limit of rainfed agriculture is assumed to be around 300–400 millimeter mean annual precipitation.
60. *Ibid.*, p. 79.
61. *Ibid.*, p. 108. Ten countries accounted for the consumption of 414 million metric tons of feed grains for livestock in 1981. This is 70 percent of the world's use of feed grains. The ten countries, in order of importance of use of feed grains, are the United States, the Soviet Union, China, Canada, France, Brazil, Japan, Poland, the Federal Republic of Germany, and Spain.
62. *Ibid.*, pp. 85, 99, and 105. Excluding pigs and poultry.
63. *Op. cit.* 1, p. 275. Grazing (range and non-range) currently supplies 64 percent of the feed consumed by beef cattle and 79 percent of the feed consumed by sheep in the United States. *op. cit.* 1, p. 289. Assuming an average of about 71 percent of the feed requirements for cattle and sheep are met by grazing, feed grains and concentrates supply about 29 percent of feed requirements. Range now supplies 22 percent of all grazing, with the remaining 78 percent supplied by non-range grazing (improved pastures, hayfields, etc.).
64. S. Sandford, *Management of Pastoral Development in the Third World* (John Wiley, New York, 1983), p. 2.
65. *Op. cit.* 59, p. 82.
66. *Op. cit.* 1, p. 253.
67. R. Dasmann, *et al.*, *Ecological Principles for Economic Development* (John Wiley, London, 1973), p. 92.
68. Excellent condition is equated with "very high potential," good with "high potential," fair with "medium potential," poor with "low," and very poor with "very low potential."
69. M.F. Heady, *Rangeland Management* (McGraw Hill, New York, 1975).
70. B. Johnson, "Forestry Crisis—What Else Is New," *IUCN Bulletin*, Vol. 14, pp. 10–12 (October/December 1983).
71. World Resources Institute (WRI), *Tropical Forests: A Call for Action* Vols. I, II, and III (WRI, Washington, D.C., 1985), p. 1.
72. L.M. Talbot, "Strengthening the Role of the Private Sector in Addressing Tropical Forestry Issues" (World Resources Institute, paper, Washington, D.C., 1985), p. 7.
73. A. Grainger, "Increasing the Effectiveness of Afforestation Projects in the Tropics Involving Non-Governmental Organizations," *International Tree Crops Journal* Vol. 3, pp. 33–48 (1984).
74. J. Spears, "Forestry Research Needs in Developing Countries" (World Bank, paper, Washington, D.C., 1981).
75. K.R. Shea and L.A.W. Carlson, *Increasing Productivity of Multi-Purpose Tree Species: A Blueprint for Action* (U.S. Department of Agriculture, U.S. Forest Service, Washington, D.C., 1985).

Photo: R. Mittermeier

6. Wildlife and Habitat

Wildlife resources include the earth's full complement of wild plants and animals, both individually as species and collectively as components of ecosystems. This year's discussion deals with maintaining diversity for both species and ecosystems. Subsequent editions of *World Resources* will treat such other topics as: wildlife management, commercial use of wild species, and the impacts and potential of new genetic technologies. Mammals, birds, fish, and plants dominate this chapter because they are the best known scientifically, and of most concern to people. Other vertebrates and invertebrates are discussed more briefly. Valuable micro-organisms are excluded here simply because few such species are known to be threatened.

Several million species of wildlife inhabit the earth. The overwhelming majority are invertebrates and plants. The numbers of species are most abundant in the tropics, and diminish toward the poles. However, gaps in data make it impossible to fully assess wildlife resources. In particular, most tropical species have scarcely been investigated, if even discovered.

This biotic wealth supplies most of our food, and much of the material we use for fuel, shelter, clothing, medicine, and other essential goods. It also provides recreation and enriches culture. Civilizations ultimately depend on the proper functioning of the ecosystems surrounding them.

Despite wildlife's importance, however, educated guesses of current species loss run to several thousand per year, and one million or more by century's end (1)—perhaps one quarter of the total now living. Human destruction of wildlife habitat causes most species loss. The destruction of tropical moist forests, where half of all species probably occur, poses a particularly serious problem.

CONDITIONS AND TRENDS

Wise management of wildlife requires attention to both species and the living systems of which they are part. Although we examine the two states separately here, they are inextricably linked.

SPECIES

When two distinguishable groups of organisms coexist without interbreeding, they are considered distinct species. However, scientists disagree on just how different two organisms must be in order to rank as species, rather than as subspecies or races. This disagreement underlies the variation in estimates of the numbers of existing species. It also influences how wildlife managers apply laws and practices.

Most species are rare; many are known from only one specimen. In an ecological zone with 100 species of birds, for instance, one dozen may be common and widespread, while the rest occur in small numbers. This phenomenon is particularly common in tropical forests, where individuals or pairs of many species are widely spaced. It makes such species more vulnerable to extinction and difficult to protect. Any low-density species requires expanses of suitable habitat to maintain healthy populations.

Of the many ways wild species serve human needs, a few stand out (2,3). Wildlife still directly provides a sizable fraction of the world's diet. A single taxon—shrimp—generates an annual retail trade worth more than $2.3 billion. Indirect uses are many. Wild forage feeds much of the world's domestic livestock. The productivity and resistance to pests and disease of domestic plants and animals rest heavily on the genetic resources of their wild or semi-domesticated relatives. About half of the world's medicinal compounds are still derived or obtained from plants (4). The value of such medicines has reached $20 billion per year in the United States, and double that amount in all the developed world. The centuries-old direct use of plants as medicine, which continues in many rural areas, represents a further unmeasured, but considerable value. Globally, trade in wood-based products now tops $100 billion annually (5), though in developing countries some three fourths of the wood harvested is burned as fuelwood, providing the principal source of energy for 2.5 billion people (6).

With the advent of genetic engineering, allowing the transfer of inherited characteristics from one species to another, the potential benefits of wild species expanded immensely. For instance, within a few years, genetic engineers hope to introduce the nitrogen-fixing capacity of a few plants into crops that now lack it. This will reduce the need for chemical nitrogen fertilizer and save the world's farmers an estimated $15 billion a year (7).

Numbers cannot describe the psychological, cultural, and spiritual values of wildlife, though money spent on wildlife-based recreation and tourism affords a hint. (See "Ecosystems," below.)

How Many Species?

To date, about 1.7 million species have been identified. (See Table 6.1.) Of these, 4,200 are mammals, 8,700 are birds, 5,100 are reptiles, 3,100 are amphibians, and 21,000 are fish. Roughly 250,000 species of vascular plants have been described (8), as have 150,000 lower plants, such as mosses and lichens (9). Invertebrates account for all the rest—nearly 1.3 million species.

The actual number of species is certainly much higher, largely because the tropics are biologically so rich and so poorly known. A widely accepted minimum figure is 5 million (10,11,12,13). Many scientists believe the total could exceed 10 million. Based on rates of discovery, the ultimate total for mammals is expected to reach 4,300 species; birds, about 9,000; reptiles, 6,000; amphibians, 3,500; and fishes, 23,000. Thus, total vertebrates are expected to reach only 45,000 species—50,000, according to some zoologists. (See Table 6.1.) Around 30,000 undescribed vascular plants are thought likely to exist, most of them in the tropics (14). The greatest number of undescribed species are invertebrates and non-flowering plants.

Table 6.1 Number of Species by Class

Class	Identified Species	Estimated Species
Mammals	4,170	4,300
Birds	8,715	9,000
Reptiles	5,115	6,000
Amphibians	3,125	3,500
Fishes	21,000	23,000
Invertebrates	1,300,000	4,400,000[a]
Vascular Plants	250,000	280,000
Nonvascular Plants	150,000	200,000
Total[b]	**1,742,000**	**4,926,000**

Notes:

[a] This figure is a minimum. Recent research suggests there could be as many as 30 million insect species in tropical forests alone.

[b] Totals are rounded.

Sources:

1. International Union for Conservation of Nature and Natural Resources (IUCN) Threatened Plants Unit, *Plants in Danger: What Do We Know* (IUCN, Conservation Monitoring Center, Cambridge, England, 1985).
2. P.H. Raven, *et al.*, 1981, Reference 8.
3. P.R. Ehrlich and A.H. Ehrlich, 1982, Reference 10.
4. E. Mayr, 1973, Reference 11.
5. N. Myers, 1979, Reference 1.
6. P.H. Raven, 1980, Reference 13.

So many invertebrates are being discovered that ultimate totals can only be guessed at. Indeed, in the late 1970s a Smithsonian Institution scientist studying caddis flies of the family Hydroptilidae collected in Amazonia found that of the 55 species represented, 53 were new (15). Another researcher suggests, on the basis of very limited findings, that the tropical forests alone could harbor 30 million insect species (16).

In reality, a close estimate of the earth's total number of species can never be attained because tropical forests, home to so many of them, are being converted to other uses at a rate of about 80,000 square kilometers per year, an area the size of Austria (17). At the same time, few scientists are qualified to describe new tropical species. Colombia, for example, has an estimated 40,000 plant species, but only a few dozen professional botanists. (In contrast, Great Britain has more botanists than its 1,445 plant species.) Worldwide, only 1,500 taxonomists and systematists study tropical organisms.

Distribution and Diversity

The world's species are distributed irregularly. Some are widespread, occurring over most of a continent or, in some cases, several continents. The osprey, for example, lives on lakes, rivers, and coasts in most parts of the world outside the polar regions. Others are exceedingly local. For example, the tiny El Segundo Blue, a critically imperiled butterfly, is confined to two small plots in Los Angeles, California; one, limited to less than half a hectare, is surrounded by an oil refinery (18). The full distribution of most species, however, is unknown.

Some of the earth's zones are much richer in species than others. As far as can be judged, some two thirds of all species occur in the tropics, which occupy 42 percent of the earth's land surface. (See Table 6.2.) More important still, half of all species apparently occur in moist tropical forests, which cover only 7 percent of the earth's land surface (19). These forests now support at least 90,000 and perhaps as many as 120,000 species of vascular plants. By contrast, the entire northern temperate zone, including North America and Eurasia, has only 50,000 species of flowering plants. If the global total is only 5 million species, tropical forests in Latin America probably support 1 million species of plants and animals, South and Southeast Asia about three quarters of a million (most in Southeast Asia), and Africa about one third of a million (20).

In certain parts of the world, where geographic or ecological isolation has promoted speciation and made species immigration difficult, endemism is high—that is, a high proportion of species live only in these areas. Of Hawaii's more than 2,400 species and varieties of flowering plants, 97 percent are endemic (21). All but four of the more than 200 cichlid fishes found in Lake Malawi in southern Africa are endemic (22). Areas with a Mediterranean type of climate—parts of California, central Chile, southwestern and southern Australia, the Cape sector of South Africa, and the Mediterranean basin itself—are restricted ecological zones with high rates of endemism. Of the 25,000 species of flowering plants in these regions, about half are endemic (23). Past ecological isolation can also produce high endemism. Drier, cooler periods during the Pleistocene are thought by many scientists to have created "islands" of tropical moist forests in the Amazon and Africa as land around them became drier savannas. Today, these forest areas still exhibit high species endemism.

Within the biologically diverse tropics, certain areas stand out as unusually diverse. Within the 1.7 square kilometers of the Rio Palenque Research Station in western Ecuador, 1,025 plant species have been found—the highest plant diversity recorded anywhere (24). Other rich areas include Brazil's Atlantic coastal forest, Central America's Mosquitia Forest, Colombia's Choco Forest, parts of Amazonia, a small slice of Madagascar, the Tai Forest of the Ivory Coast, the montane forests of East Africa, the relict wet forest in Sri Lanka, the monsoon forests of the Himalayan foothills, northwestern Borneo, the Maldive Islands, certain Philippine lowlands, and several South Pacific islands, notably New Caledonia.

Many of these areas have a high degree of endemism as well as biological diversity. Thus, they are doubly important for species conservation. Yet, already some are largely destroyed as natural areas, and the others are rapidly being degraded.

Table 6.2 Number of Species by Climatic Zones

Zone	Identified Species (millions)	Estimated Species (millions)	
		Assuming 5 million total	Assuming 10 million total
Boreal	0.1	0.1	0.1
Temperate	1.0	1.2	1.3
Tropical	0.6	3.7	8.6
World	**1.7**	**5.0**	**10.0**

Sources:
1. International Union for Conservation of Nature and Natural Resources (IUCN), Threatened Plants Unit, *Plants in Danger: What Do We Know* (IUCN, Conservation Monitoring Center, Cambridge, England, 1985).
2. P.H. Raven, *et al.*, 1981, Reference 8.
3. P.R. Ehrlich and A.H. Ehrlich, 1982, Reference 10.
4. E. Mayr, 1973, Reference 11.
5. N. Myers, 1979, Reference 1.
6. P.H. Raven, 1980, Reference 13.

Coral reefs also play host to unusually high numbers of species. For example, preliminary surveys of the Ningaloo Reef Tract, a fringing reef running for 260 kilometers along Australia's west coast, have recorded 170 species of corals, 90 echinoderms, about 600 mollusks, and 480 fish (25).

At the low end of the diversity spectrum are ice caps, tundra, and boreal forests. Canada, much of which is tundra or boreal forest, has only 22 species of snakes, while Mexico has 293 (26). As discussed below, regions of low diversity require a different conservation approach than do high-diversity zones.

THREATENED SPECIES

Conservation and management of wildlife resources to date have focused largely on species with known economic value, such as timber and fruit trees, certain marine fish, and game species, especially mammals and birds. But a broader approach is now beginning to take hold—one in which *all* species are considered valuable, and attention is being directed toward those in known difficulty: "threatened species."

The International Union for Conservation of Nature and Natural Resources (IUCN) lists three major types of threatened species: those *endangered* because of near-term threats to the regenerating populations; those that are *vulnerable* over time because populations are declining in number or geographical distribution; and species that are *rare* because their total population is small or restricted in area. IUCN's Conservation Monitoring Center maintains data bases on globally threatened species and periodically publishes and updates the *Red Data Books* on major groups of plants and animals. These books highlight the world's most critically threatened species. Perhaps their most important benefit has been to stimulate local and national efforts to list threatened species and publish regional red data books.

Temperate Zone

Some of the best data on temperate zone wildlife trends come from replies to questionnaires distributed by the Organization for Economic Cooperation and Development (OECD), and from the annual breeding bird survey conducted by the U.S. Fish and Wildlife Service. The OECD study shows that among declining mammals, large species (including grizzly and polar bears, wolves, wild cats, and the blue, humpback, and sperm whales), figure prominently. A few species, such as the white-tailed deer, beaver, coyote, raccoon, and some rats, are expanding in number or territory, largely as a result of habitat modification or translocation by people. In OECD countries, roughly one fourth of all mammals have been officially identified as threatened. In West Germany, the Netherlands, Austria, and Spain, more than 40 percent of all native mammalian species are threatened (27). (See Table 6.3.)

Birds appear to be slightly better off than mammals in terms of both population trends and percentages of species threatened. Species that require undisturbed habitat

Table 6.3 Status of Species in Selected OECD Countries, Early 1980s

	Mammals					Birds					Reptiles				
	Species Known	Threatened[a]		Decreasing		Species Known	Threatened[a]		Decreasing		Species Known	Threatened[a]		Decreasing	
		Number	%	Number	%		Number	%	Number	%		Number	%	Number	%
Canada	94	6	6.4	5	5.3	434	10	2.3	8	1.8	32	2	6.3	5	15.6
United States[b]	466	35	7.5	X	X	1,090	69	6.3	X	X	368	25	6.8	X	X
Japan	186	4	2.2	A	A	632	35	5.5	A	A	85	3	3.5	A	A
Australia	320	43	13.4	X	X	700	23	3.3	X	X	550	9	1.6	X	X
New Zealand	68	14	20.6	21	30.9	282	16	5.7	46	16.3	37	7	18.9	7	18.9
Austria[c]	83	38	45.8	X	X	201	121	60.2	1	X	X	X	X	X	X
Denmark	49	14	28.6	16	32.7	190	41	21.6	68	35.8	5	0	0.0	4	80.0
Finland	62	21	33.9	11	17.7	232	15	6.5	24	10.3	5	1	20.0	1	20.0
France[d]	107	34	31.8	30	28.0	264	79	29.9	X	X	32	4	12.5	X	X
Germany[c, e]	94	44	46.8	A	A	455	98	21.5	A	A	12	9	75.0	B	B
Italy	97	13	13.4	35	36.1	419	60	14.3	X	X	46	24	52.2	25	54.3
Netherlands[e]	60	29	48.3	28	46.7	257	85	33.1	52	20.2	7	6	85.7	6	85.7
Norway	71	10	14.1	3	4.2	280	28	10.0	17	6.1	5	1	20.0	0	0.0
Portugal	79	X	X	X	X	337	X	X	X	X	24	X	X	X	X
Spain[f]	100	53	53.0	34	34.0	389	142	36.5	122	31.4	49	20	40.8	13	26.5
Sweden	63	11	17.5	X	X	250	34	13.6	X	X	6	0	0.0	X	X
Switzerland	86	X	X	X	X	190	74	38.9	X	X	15	X	X	X	X
Turkey	31	11	35.5	11	35.5	217	36	16.6	81	37.3	X	X	X	X	X
United Kingdom[g]	51	12	23.5	X	X	200	24	12.0	X	X	6	2	33.3	X	X

Capital letters in the table refer to estimates of the number of species in each category.
A = several species B = many species X = not available

Notes:
a. Threatened refers to the sum of the number of species in the endangered and vulnerable categories.
b. Including Pacific and Caribbean Islands.
c. Data for threatened animals include extinct and/or vanished species.
d. Data for known freshwater fish species only.
e. The number of bird species known includes occasional visitors.
f. Peninsular Spain and the Baleares only.
g. Data refer only to terrestrial mammals.

Source: Organization for Economic Cooperation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985).

and nesting sites or somewhat rare foods—the black woodpecker (*Dryocopus martinus*) in Norway, for instance—have declined, while pigeons, gulls, egrets, sparrows, and other birds that adapt well to the presence of people have increased and spread. Austria, Switzerland, Spain, and the Netherlands have the largest percentages of threatened birds—between 33 and 60 percent. An annual survey of breeding birds conducted by the U.S. Fish and Wildlife Service in the continental United States and Canada shows significant increases in population for 64 species (16 percent) and significant declines for 48 (12 percent) between 1968 and 1979 (28). Two major factors influenced these results. One was bird die-offs in the late 1960s due to the use of long-lasting pesticides such as DDT. Another was massive outbreaks of the spruce budworm, which boosted food supplies in northern forests during the 1970s.

Reptiles and amphibians appear to be even harder pressed than mammals and birds in OECD countries, especially European countries. Denmark, for instance, reported that four of its five reptile species and *all* of its 14 amphibians are decreasing. West Germany, Italy, the Netherlands, and Spain all reported over 40 percent of their reptile and amphibian species as threatened.

Among vertebrates, fishes (including many noncommercial marine species) appear the least threatened in OECD countries. Many countries, however, are adding more fish to their official lists as better information is obtained. Most decreases in fish populations are attributed to the loss of breeding and nursery grounds because so many wetlands, bays, estuaries, and coastal marshes have been filled or polluted. Overfishing has decimated some important commercial species, such as Atlantic herring and haddock.

A few countries reported small numbers of threatened invertebrates. (More data would probably put many more species in this category.) Nine countries submitted information on numbers of threatened plants—which ranged from near zero to West Germany's 29 percent. This suggests that the OECD countries approximate the world average for endangered plants (10 percent) roughly estimated by IUCN (29).

Tropical Zone

Data on population trends for tropical species are few, but many tropical forest species are undoubtedly declining, simply because their habitats are rapidly being cleared, and few tropical species can survive anywhere else. Of 401 bird species and sub-species listed as threatened in the *Red Data Books*, 291 live in tropical moist forests (30). Of key concern are the forest areas where species diversity and endemism are unusually high.

Farming, grazing, fires, firewood cutting, and desertification are altering tropical savannas and grasslands too. Along with hunting, these changes are reducing the number of larger animal species, especially mammals, and probably many smaller ones. In general, however, savanna species seem better able to survive on farms and other altered habitats than tropical forest species. Some, like the black-faced dioch (a grain-eating bird) and various species of locusts, thrive and become serious pests.

Information on threatened species by country is available for Latin America. "Diversity profiles" have been generated from the U.S. Nature Conservancy's computerized data base on the status of habitat conservation, major ecosystems, and terrestrial vertebrate species throughout the neotropical region (31). (See Table 6.4.) For

Amphibians					Fishes				
Species Known	Threatened[a]		Decreasing		Species Known	Threatened[a]		Decreasing	
	Number	%	Number	%		Number	%	Number	%
54	2	3.7	2	3.7	800	15	1.9	X	X
222	8	3.6	X	X	2,640	44	1.7	X	X
58	1	1.7	A	A	3,144	4	0.1	A	A
150	6	4.0	X	X	3,200	X	X	X	X
6	X	X	2	33.3	777	3	0.4	77	9.9
X	X	X	X	X	92	54	58.7	X	X
14	3	21.4	14	100.0	166	17	10.2	20	12.0
6	0	0.0	1	16.7	58	4	6.9	10	17.2
30	6	20.0	X	X	70	13	18.6	X	X
19	11	57.9	B	B	173	40	23.1	A	A
28	13	46.4	26	92.9	503	70	13.9	112	22.3
15	10	66.7	8	53.3	49	11	22.4	A	A
5	1	20.0	3	60.0	X	X	X	X	X
17	X	X	X	X	X	X	X	X	X
23	18	78.3	4	17.4	137	12	8.8	5	3.6
11	5	45.5	X	X	X	X	X	X	X
20	X	X	X	X	60	X	X	X	X
X	X	X	X	X	X	X	X	X	X
6	2	33.3	X	X	37	8	21.6	X	X

the region, 11 percent of the 3,812 bird species, 11 percent of the 1,234 mammals, 5 percent of the 2,420 reptiles, and less than 1 percent of the 1,833 amphibians have been listed as threatened. By country, the percentage of vertebrate species threatened ranges from 8 percent for Mexico to 15 percent for Paraguay and Uruguay. Compared to the OECD countries, Latin America and the Caribbean appear to be much healthier with respect to species populations, probably in part because human density is lower in the neotropics. (Better information from the OECD countries could also account for some of the difference.) Human pressure is increasing, however, especially on tropical forests.

Similar data are not yet available for tropical Asia. For Africa, numbers of globally threatened mammal species have been determined on a country-by-country basis. (See Part IV, "Wildlife Resources," Table 7.3.) The number of species threatened ranges from zero in São Tome to 17 in Zaire and 18 in Nigeria.

Scientists express greatest concern for threatened African plants in South Africa and Madagascar. Plant diversity, endemism, and the degree of threat are high in both countries, though data are more complete for South Africa. The Cape Floristic Kingdom in southwestern South Africa, one of the world's botanically richest and most distinctive areas, harbors 6,000 plant species, 70 percent of them endemic. Mainly because of agricultural activity, fires, and invasion of exotic plants, at least 2,000 are threatened (33).

Wetlands and Oceans

Many wetland species are declining because of habitat reduction and degradation. In the United States, for example, 40 percent of the wetland areas have been drained or filled since 1850, endangering approximately half of all U.S. freshwater mollusk species (34). In Great Britain, almost all amphibians—even the common frog—are threatened.

In the oceans, hunted species of whales have declined. Even with harvesting quotas for some species and whaling bans on others, whale stocks are not recovering (35). The California gray whale is the one exception. (See Figure 6.1.) Coral reef species are declining too as a result of coral removal and dynamite fishing.

VULNERABLE GROUPS

Certain inherent characteristics make some species more vulnerable than others. The populations of many threatened species have always been small and local, either because they evolved in unique geographic situations or because they required certain rare foods or habitats. For instance, the Kirtland's warbler (*Dendroica kirtlandii*) is now reduced to about 400 individuals in the United States in northern Michigan. This warbler can breed only in thickets of young jack pines that spring up after fires—a habitat found in only a few states and Canadian provinces. Such isolated and inbred populations are especially vulnerable to severe weather, epidemics, or other catastrophic events.

Island species are also unusually vulnerable. Many have evolved on islands with few if any predators or herbivores. As a result, they lack such normal defense mechanisms as flight in birds, or poisonous chemicals and spines in plants. When people introduce predators or herbivores to islands, many native species are wiped out. The flightless dodo on Mauritius is a familiar example. On St. Helena, which was settled by Europeans in the 16th Century and overrun with their goats, 22 of 33 endemic plant species have disappeared since 1810 (36).

Animal species that either forage or breed in large aggregrations are also susceptible to decimation. Some, including certain whales and dolphins, expose themselves to danger by coming to the aid of dead or wounded members of the group. Those that require large breeding colonies may, like the passenger pigeon (*Ectopistes migratorius*), fail when their populations fall below a certain size due to hunting or other causes.

Slow reproducers, often large mammals or birds, represent another vulnerable group of species. These species can maintain their populations in natural situations because their young enjoy high survival rates. But their recovery from catastrophe or human exploitation is very slow. The California condor—now down to fewer than 10 individuals in the wild—does not breed until at least six years of age, lays only one egg, and fails to nest at all in some years. A pair of condors thus requires 10–15 years to replace itself (37).

Finally, some species require large areas to maintain themselves, or for other reasons occur at very widely spaced intervals. Large carnivores need expansive hunting territories to find enough prey, and hornbills need great amounts of space in which to find food. In several African parks, lions require anything from one to 40 square

Table 6.4 Status of Resident Terrestrial Vertebrates in Latin America, 1985

Region or Country	Mammals		Birds		Reptiles		Amphibians		Total	
	Total Number	% Threatened or Endangered[a]	Total Number	% Threatened or Endangered[a]	Total Number	% Threatened or Endangered[a]	Total Number	% Threatened or Endangered[a]	Total Number	% Threatened or Endangered[a]
Latin America and the Caribbean	1,234	11	3,812	11	2,420	5	1,833	1	9,299	7
Mesoamerica Region (Mexico and C. America)	559	8	1,318	12	930	4	505	1	3,312	7
Tropical Andean Region	602	14	2,518	10	823	6	818	0	4,761	8
Guiana Region	330	12	1,354	11	286	10	229	0	2,199	10
Tropical Atlantic Region	419	19	1,598	13	475	8	491	0	2,983	11
Southern Cone Region	284	17	1,007	12	266	8	156	0	1,713	11
Caribbean Islands Region	141	13	639	16	434	12	138	1	1,352	13
Mexico	439	7	958	13	702	5	273	1	2,372	8
Guatemala	174	12	666	14	201	8	98	0	1,139	12
Belize	121	15	505	13	109	10	24	0	759	13
Honduras	179	13	670	13	154	8	53	0	1,056	12
El Salvador	129	12	431	15	86	12	36	0	682	13
Nicaragua	177	14	609	13	165	10	58	0	1,009	12
Costa Rica	203	13	795	12	220	8	151	1	1,369	10
Panama	217	14	840	12	207	9	155	1	1,419	10
Colombia	358	17	1,665	11	371	9	362	1	2,756	10
Venezuela	305	12	1,295	11	244	10	176	0	2,020	10
Guyana	198	14	732	13	136	14	106	0	1,172	12
Suriname	200	16	674	13	130	14	99	0	1,103	13
French Guiana	142	20	627	13	135	16	90	0	994	13
Brazil	394	20	1,561	13	462	8	479	0	2,896	11
Ecuador	280	18	1,449	11	344	8	349	0	2,422	10
Peru	359	17	1,640	10	291	8	233	0	2,523	10
Bolivia	267	19	1,179	12	174	10	96	0	1,716	12
Chile	90	20	393	10	80	5	40	0	603	10
Argentina	255	16	927	13	204	8	124	0	1,510	12
Paraguay	157	21	629	16	111	11	751	0	966	15
Uruguay	77	29	368	13	65	15	35	0	545	15
Cuba	39	23	286	13	98	16	39	0	462	13
Hispaniola	23	17	212	12	133	8	53	0	391	10
Puerto Rico	17	12	221	13	46	20	25	[illegible]	309	13
Jamaica	29	10	223	10	38	18	20	[illegible]	310	10
Bahamas	17	18	219	8	39	31	2	0	277	12
Lesser Antilles	37	11	193	14	91	13	15	0	336	13
Tobago	29	10	160	11	39	26	8	0	236	13
Trinidad	85	7	347	15	74	19	14	0	520	14
Netherlands Antilles	9	22	171	10	22	18	2	0	204	11

Note:

a. Listed on CITES Appendices I, II, and III; on U.S. Department of Interior Fish and Wildlife Service threatened and endangered species list; or in the International Union for Conservation of Nature and Natural Resources (IUCN) *Red Data Books*.

Source: The Nature Conservancy International Program (TNCIP). The Latin American/Caribbean Regional Conservation Data Center (TNCIP Typescript, Washington, DC, 1985).

kilometers each. Grizzly bears in Yellowstone National Park in the United States have, on average, 50 square kilometers each (38). Many tropical trees are widely spaced too, though each individual uses the resources of a relatively small area. Without large areas of suitable habitat, such species will dwindle or even die off.

Causes of Depletion

Besides the enormous losses resulting from habitat destruction, direct, targeted depletion threatens many species. A common form is overhunting for meat, furs, and other products. Among obvious examples are the great whales, seals, the California sardine, wild cats (such as the tiger, clouded leopard, and cheetah), and the now-extinct great auk.

Probably the most salient recent instance of direct depletion is the African rhino. In 1980, the black rhino population stood at 15,000, but by 1985 fewer than half that number remained. (In the Central African Republic, numbers plunged from 3,000 to about 150.) As for the white rhino, the southern race has increased slightly, but the northern race has dropped from almost 1,000 to at most one dozen (39). The three species of Asian rhinos, though somewhat better protected, are equally threatened, with numbers of the rarest—the Javan rhinoceros—down to about 50.

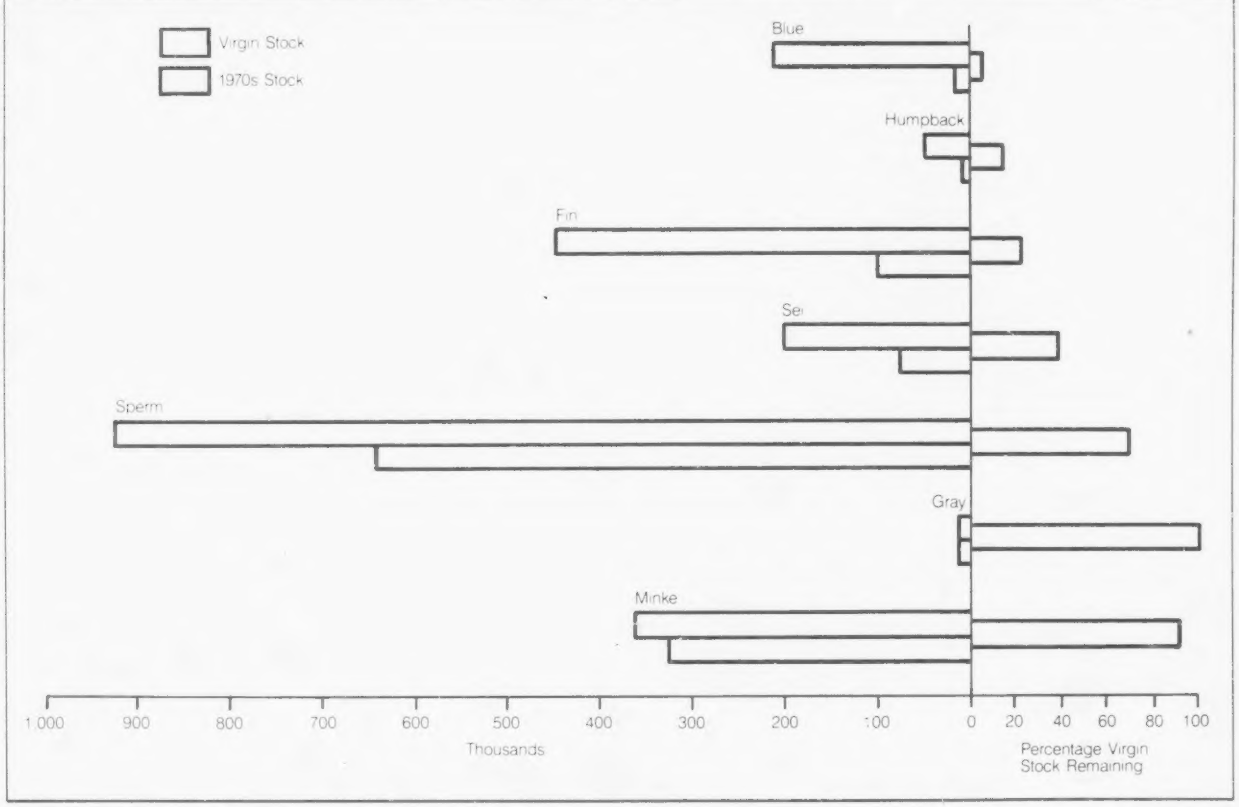
African elephants are overhunted for their ivory. Ivory exports of about 1,000 tons per year represent 90,000 or more dead elephants—almost twice the 5 percent annual cropping that the estimated one million or so elephants left in Africa can sustain. Although the number of elephants surviving in Africa, especially in the vast forests of the Zaire Basin, is uncertain, a 10 percent annual kill could halve remaining populations within a decade.

Trade in live plants and animals has taken its toll on many species. Among plants, orchids and cacti are prime targets. In 1977, U.S. legal imports of succulents, mostly cacti, from Mexico totaled 7 million plants. Illegal, hence unrecorded, imports are also substantial. U.S. imports of one Mexican cycad were believed to have wiped out the entire wild stock of the species (40). In 1983, 29 golden-headed lion tamarins, a severely threatened primate from coastal Brazil, were imported into Belgium (41). Scientists believe that fewer than 1,000 of these animals remain in the world.

Extinction

Species extinction has occurred since life's emergence on Earth almost 4 billion years ago. Of the estimated half billion species that have ever existed, modern survivors today probably number 5 to 10 million species. But

Figure 6.1 Whale Exploitation, by Species, Pre-hunting through the 1970s



Sources:
1. V.B. Scheffer, "The Status of Whales," *Pacific Discovery*, Vol. 29, No. 1, p. 3 (1976).
2. W.E. Scherill, Ed. *The Whale Problem: A Status Report* (Harvard University Press, Cambridge, Massachusetts, 1974), pp. 306–307.
3. Committee for Whaling Statistics (CWS), *International Whaling Statistics* (CWS, Sandefjord, Norway, 1979), p. 12 and p. 17.

almost all past extinctions have occurred naturally. Only in the past 50,000 years or so have people exerted much influence as hunters, food-gatherers, and cultivators. And only in the past four centuries has advancing technology made possible massive human-caused losses of habitat and species.

Predictions of species losses by the end of this century, based on recent land-use trends, rise to a million or more. Some scientists believe that almost 20 percent of all species live in Latin American forests outside of Amazonia and that another 20 percent live in the forests of Asia and Africa outside the Zaire Basin. *All* of these forests may well disappear within the next 25 years or so. If only half of the species they contain disappear, at least three quarters of a million of Earth's estimated 5 million species will die (42). In the next century, if present rates of forest loss continue, one third or more of all species could be lost—a mass die-off that would rival past extinctions that occurred over millions of years (43).

PROTECTION OF THREATENED SPECIES

Methods to protect threatened species include legislation, habitat protection, wildlife management, and maintenance of individuals in zoos, botanical gardens, and other artificial habitats.

The starting point for protection of species has always been laws, regulations, and policies. Most early laws dealt with game animals, fish, and migratory birds. More recent legislation also protects reptiles, amphibians, invertebrates, and plants. A far-reaching example of a law directed solely at threatened species is the 1973 U.S. Endangered Species Act. This legislation was enacted to protect the species officially listed as endangered and their "critical habitat." The law also initiated recovery programs. To date, about 370 species or subspecies have been listed as endangered or threatened under the law, and some 185 recovery plans for species or groups of species have been approved (44). Most countries outside the OECD also have laws protecting at least some species, but enforcement varies greatly from country to country.

Several international treaties and conventions now protect wildlife species, but most are bilateral or regional. Among the most far-reaching is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), administered by the United Nations

Environment Program (UNEP). Since CITES came into force in 1975, 87 countries have become parties, and more than 700 species have been listed (45). Although nearly all the main producer and consumer nations are parties to the Convention, notable exceptions include New Zealand (which implements many CITES provisions) and Singapore (which is a major center for distributing wildlife and wildlife products). Certainly more nations need to accede to the treaty. Other weaknesses of this protection system include failures to report trade statistics to central information clearinghouses and the lack of implementing legislation in some countries.

By far the most effective way to protect species is to provide ample secure habitat. Most of the thousands of protected areas around the world were not established primarily to benefit one or a few species. Many, however, do harbor threatened species. Geneticists believe that 50–250 individuals of most mammalian species are needed in such areas for healthy breeding (46). Given the possibility of local catastrophes and other dangers, many wildlife scientists put that figure at several hundred or several thousand individuals for a plant or animal species. As for space needs, a viable population of a species of butterfly might be sustained within a few square kilometers, whereas grizzly bears may require more than 20,000 square kilometers.

Among the protected areas established primarily for one species are such diverse sites as the tiny Addo Elephant National Park in South Africa and ten reserves established in China for the giant panda. Under Project Tiger in India, a dozen or so new reserves were created and others expanded, in part to broaden the range of ecosystems under protection. As a result, India's tiger population rose from about 1,800 in 1972 to around 4,000 today; swamp deer, Asian elephants, rhinos, wild water buffalos, and other rare species benefited as well.

Close management of a threatened species in the wild can succeed when its population dynamics are well understood and its economic or other value has been recognized. An outstanding example is the vicuna recovery in the Andes. In Peru and other countries, the vicuna declined because of overhunting for its valuable fur. Only 7,500 animals survived in the late 1960s (47). New controls on cropping, hunting, and pasture use have pushed the population to almost 100,000 today.

Efforts to protect species by sequestering individuals in zoos, botanical gardens, and seed banks are a last resort. Zoos and botanical gardens have room for relatively few species and individuals, and maintenance costs are high. But captive breeding and the reintroduction of eggs or young to the wild has sometimes proven effective, as with the peregrine falcon and some crane species. In gene banks, the seeds of many plant species (especially those with dry, small seeds) can be stored dormant for long periods. The Fort Collins facility of the U.S. Department of Agriculture contains 100,000 samples of more than 1,300 plant species, with a capacity for at least 500,000 samples. But this technique does not work with most vegetatively propagated plants (such as orchids) and many other tropical species. Also, refrigerated storage in effect freezes evolution, possibly rendering stored material less fit to meet changes that meanwhile occur in its natural environment.

However costly and time-consuming, the species approach to wildlife conservation is sometimes necessary. In practice, though, more of the larger spectacular species (especially mammals) get saved. Protecting such species does win public support. And while it automatically provides sanctuary for many smaller forms, it is usually less effective than conserving wildlife resources by preserving whole ecosystems.

ECOSYSTEMS

The survival of wildlife populations depends primarily on the extent and condition of their habitats. Thus an assessment of the world's great range of ecosystems—communities of species and their physical environment—is essential. (See Figure 6.2.)

All of the earth's environments have been altered by human activity, some drastically. How well wild species adapt to such alterations largely determines their future. Few species can tolerate much environmental disturbance, so their survival depends on preventing or managing disturbance in protected areas.

Ecosystems have values besides those of the wildlife. Expenditures in the United States for non-consumptive recreation associated with wildlife and its habitat were estimated at $14.8 billion in 1980. U.S. expenditures by hunters and fishermen on fees, transportation, equipment, food, and lodging rose from $5.7 billion in 1960 to $16 billion in 1980 (in constant 1975 dollars) (48). The value of tourism and recreation in other countries is not nearly so large, but can constitute a greater share of national economies. In Kenya, for example, safari-centered tourism is the second most important source of foreign exchange after coffee.

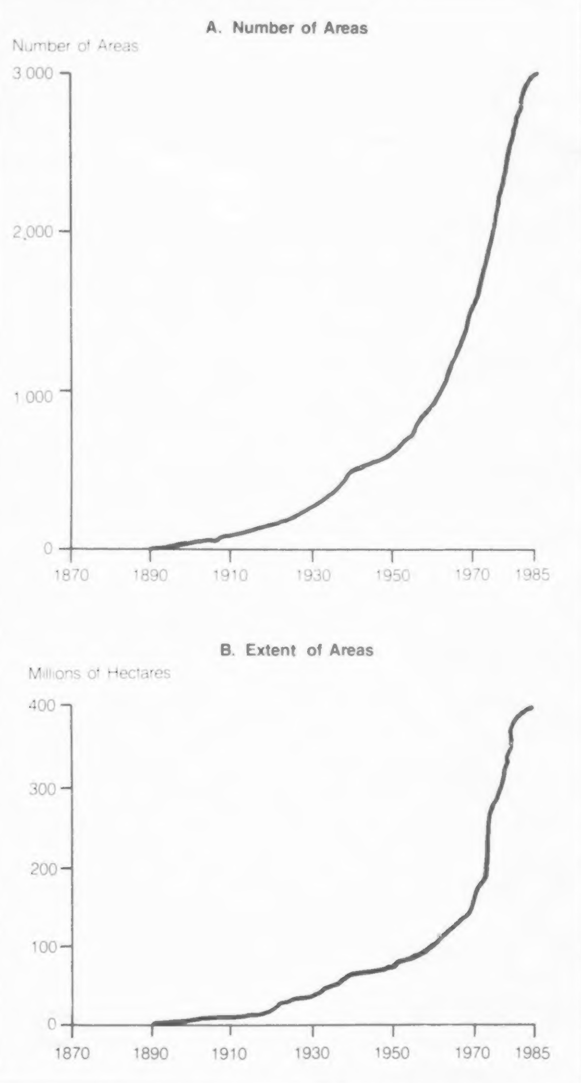
Ecosystems also supply environmental services. They maintain the quality of the atmosphere by balancing amounts of nitrogen, oxygen, and other critical gases. They control and ameliorate climate and weather by profoundly influencing the global patterns of air circulation. They regulate freshwater supplies, dispose of wastes, recycle nutrients, and generate, maintain, and protect soils. Often, these "free" environmental services are not appreciated until an ecosystem is disrupted—until, for instance, a watershed is deforested and downstream areas flood or fill with sediment.

Extent and Condition of Ecosystems

Global estimates of the size of major ecosystems and changes in their extent are sketchy, though improving with the quality of satellite imagery. A study of global land use showed that cultivation now occupies 17.46 million square kilometers (13 percent) of the earth's surface (49). (See Table 6.5 and Part IV, "Land Use and Cover," Table 4.2 for details.) Most of this was once grassland, forest, or woodland.

In terms of total area lost, the greatest reduction since pre-agricultural time has occurred in forests, especially temperate forests. While such forests have slightly

Figure 6.2 Growth of the Global Network of Protected Areas, 1890–1985



Source: International Union for Conservation of Nature and Natural Resources (IUCN), 1985. Reference 62.

increased in extent recently, their wildlife has not necessarily increased proportionately. Much of the expansion is in monocultural forest plantations, which support comparatively few species. Mature forests, with their greater biological diversity, have decreased, and younger stands now predominate. Acid precipitation has devastated some forests in Europe and has begun to affect others in North America. Forest fragmentation in much of the temperate zone renders many forest patches too small to support some species. Losses of tropical rain forests have accelerated over the past three decades. Thus, though this land use study—whose sources date largely from the beginning of this period—shows only a 4 percent loss in their original extent, estimates based on more recent data show losses of 25–40 percent (50).

Estimates of the current rate of conversion of tropical moist forest to other uses are uniformly high. A conservative estimate is that 12 percent of the 1980 extent of these forests will be lost by the year 2000 (51). Thailand may lose 60 percent; Guinea, 33 percent; Nigeria and the Ivory Coast, 100 percent; Costa Rica, 80 percent; and Honduras, Nicaragua, and Ecuador, at least 50 percent. (See Chapter 5, "Forests and Rangelands.")

The principal agent in the conversion of tropical forests is the slash-and-burn cultivator. The problem lies not so much with traditional shifting cultivators as with the *shifted* cultivators who find themselves landless in established farmlands. They head for the last unoccupied, "free" land available—the forests. In many countries, including the Philippines, Indonesia, Thailand, Madagascar, Ivory Coast, Kenya, and Guatemala, the numbers of slash-and-burn farmers are increasing by 4–7 percent each year. Worldwide, they now number at least 250 million, and the pressures they exert on land are expected to grow (52).

Countries such as Brazil, Indonesia, and Malaysia design large agricultural schemes to provide plots for the landless. These schemes require big chunks of forest. In Latin America, cattle ranching for the export trade plays a major role. Government figures attribute 38 percent of all deforestation in the Brazilian Amazon between 1966 and 1975 to large-scale cattle ranches, 31 percent to other agriculture, and 27 percent to highway construction (53).

Logging affects large areas because tropical tree species grow in low densities, and relatively few have commercial markets. Selective logging alone seldom destroys a forest, but the subsequent invasion of farmers along logging roads often does. Hydroelectric dams, mines, and other development projects also contribute to deforestation.

In total, conversion plus various degrees of degradation now probably affect about 200,000 square kilometers of moist tropical forest per year (54). How the alteration of tropical forests affects wildlife is poorly documented. Many experts concur that rending the fabric of a rain forest will unravel the whole system. Surveys of selectively logged forests in Southeast Asia suggest, however, that most primate and bird fauna, at least, return within 30–50 years if mature forest is available nearby as a refuge and source of recolonization (55).

Table 6.5 Land Use and Cover, Pre-Agriculture to the Present

	(million square kilometers)			Relative
Vegetation Type	Preagricultural Area	Present Area	Absolute Amount Lost	Loss (percent)
All Forests	49.86	42.10	7.76	16
Tropical rainforests	12.80	12.30	0.50	4
Other forests	37.06	29.80	7.26	20
Woodland	12.32	10.44	1.88	15
Shrubland	13.12	12.15	0.97	7
Tundra	7.35	7.35	0.00	0
Grassland	34.01	27.45	6.56	19
Desert	15.85	15.58	0.27	2
Cultivation	0.00	17.46	NA	NA
Total	**132.51**	**132.51**	**17.46**	**13**

NA = not applicable
Source: E. Matthews, 1983. Reference 49.

Losses of the earth's original grasslands amount to 19 percent, though in the OECD countries total grassland area did not change from 1955 to 1983 (56). Most grasslands are subject to livestock grazing, which can reduce the number of palatable species of grass. This creates niches for invasive exotic weeds. In Australia, grazing contributed to the decline of many marsupials (57). In Africa and elsewhere, annual burning reduces the abundance of woody species and alters the composition of grass species, thus depriving some wild animal populations of food and cover. Hunting and livestock grazing have held the numbers of wild animals on grasslands far below their potential. Dryland agriculture is another common cause of grassland loss. It can lead to a long-term loss of habitat and of agricultural and range productivity.

While woodland losses amount to only about one-third that of forests or grasslands, the area represents almost 14 percent of the original extent of this ecosystem. The largest area affected is the dry African miombo, a fairly dense, short woodland where subsistence farming is widely practiced. In many areas, fire, grazing, hunting, and firewood-cutting have impoverished the wildlife resources of remaining woodlands.

Shrublands, generally too arid, cold, or mountainous for agriculture, have decreased by only 6.7 percent since preagricultural times. Fire, grazing, woodcutting, hunting, and drought have turned many shrublands and grasslands into near-deserts, thus transforming wildlife habitat. Shrubland is important for its hydrologic regulation in steep areas, as well as for wildlife habitat.

Though some confusion exists over how to define and measure desert, desertlike conditions appear to be spreading worldwide. Off-road vehicle use in arid lands has damaged plant communities considerably, especially in such settled deserts as those of southwestern United States. In the Sahara, shooting by the military and commercial hunting have nearly wiped out the scimitar-horned oryx, dama gazelle, and ostrich, while populations of other animals are dwindling (58). In contrast, other desert species are expanding as shrublands and grasslands desertify.

The area of tundra has not changed. The principal human impact on this environment has come through reindeer herding in northern Eurasia, oil and mineral exploration and production, and hunting and trapping—activities that have depleted populations of the barren-ground caribou and musk-oxen. Trampling and machinery use have also damaged tundra soils and vegetation, which are slow to recover.

Antarctica and other ice-covered regions have virtually no vegetation, but do have some wildlife. Seals, polar bears, and birds (including penguins) all ultimately depend on the sea for food. Hunting, and perhaps krill harvesting, have taken a toll on these resources, but currently they are relatively stable.

Although wetlands—home to economically important groups such as fish and waterfowl—are difficult to measure on a global scale, the area of marshes, ponds, swamps, and bogs has been shrinking rapidly. In the United States, 40 percent of all wetlands has been drained or filled since 1850 (59). In Japan, 33 percent of the tidelands, where shellfish and birds feed, were lost between 1945 and 1978 (60). The Pantanal in Brazil, at 110,00 square kilometers probably the world's most extensive wetland, is being encroached upon by agriculture.

In many parts of the world, both wetlands and lakes are subject to acid deposition and pollution from other sources. Lakes in parts of Europe, Canada, and the United States are especially threatened. One species of Canadian trout has been brought close to extinction as more and more Canadian lakes acidify (61).

FOCUS ON: PROTECTED AREAS

The most effective defense against loss of wildlife is to establish and maintain protected areas. Conservationists, therefore, are working to create a worldwide system of protected areas as habitats for viable populations of most existing species—a permanent genetic pool of the earth's natural variety.

Besides national parks, many types of protected areas have evolved in recent decades. They range from scientific reserves to multiple-use areas where some exploitation, such as logging or hunting, is permitted. As human material needs grow, alternatives to the national park concept are being sought to better serve the many poor people who cannot afford to forego the consumption of natural resources for the sake of recreation and aesthetic enjoyment.

More than 3,500 major protected areas, totaling 4.25 million square kilometers, are included in IUCN's *1985 United Nations List of National Parks and Protected Areas* (62). The growth rates in the extent and number of protected areas rose particularly rapidly after 1950, especially in the non-OECD countries where the concept was comparatively new. (See Figure 6.3.)

Most protected areas on the U.N. list are between 1,000 and 100,000 hectares in size. A few dozen total over 1 million hectares each, including Greenland National Park, by far the largest at 70 million hectares. The average size of reserves is greatest in the Afrotropical and Nearctic Realms, where human settlement is sparse.

By country, the percentage of total area in protected status varies widely. Only about a dozen countries over 20,000 square kilometers in size have over 10 percent of their land in protected areas. These tend to be in Africa. Most countries fall below 5 percent, and a few have no protected areas at all. (See Table 6.6.) Quality of management and degree of protection also vary widely.

Existing protected areas have been classified by IUCN according to current management practice rather than title or management intent. (See Part IV, "Wildlife Resources," Technical Notes.) This ten-category framework permits international comparisons. The first five categories, the most significant for wildlife conservation, are used in the analysis below. At the Conservation Monitoring Center in Cambridge, England, IUCN maintains a data base providing information on location, size, management, and biological resources for national parks, wildlife reserves, national monuments, biosphere reserves, and other types of areas. Information on smaller conservation areas, such as private reserves or state parks, is also being accumulated.

Biogeographical Zones

IUCN also classifies and maps biogeographical zones. Its system for assessing terrestrial environments, known as the Udvârdy classification (63), divides the world's land areas into eight major *realms* that are subdivided into 207 *provinces*. Each province, in turn, is characterized by one of 14 major *biome* types. For example, California's Sequoia National Park lies within the Nearctic Realm and the Sierra-Cascade Province, which is characterized as a Mixed Mountain and Highland System Biome. A second classification divides marine and coastal environments into *Ocean Realms*, *Coastal Realms*, and *Marginal Seas and Archipelagoes*, with 40 resulting *Faunal Provinces* along the coastlines (64). However, detailed classification of marine and coastal protected areas has not yet been completed.

Though useful, the biogeographical zone classification scheme can mislead (65). For example, the Palearctic Realm includes 122 protected areas covering 84,634 square kilometers in the Temperate Needle-Leaf Forests/Woodlands Biome, but only 9 areas covering 521 square kilometers in the Mixed Islands System Biome. Yet the former biome is not necessarily better protected since it contains most of Asia between 55°N and the Arctic Circle and much of Europe, while the Mixed Island System Biome contains only the Macronesian Islands and Ryukyu Islands (totaling about 17,820 square kilometers) Also, summaries of the coverage of biomes and biogeographical provinces by established protected areas tell little about the quality of management of these areas or the real protection afforded to ecosystems and species within them.

Protected areas have been established in all but 1 of the 14 biomes, although the number of areas and the total area protected vary greatly. Only the Lake Systems Biome within the Neotropical Realm has no protected areas. (See Table 6.7.) Other biomes are of concern because they have very few protected areas or have less than 1,000 square kilometers protected. (See Figure 6.2.)

Of the biogeographical provinces, 15 have no protected areas, and 30 have five or fewer protected areas *and* an area of less than 1,000 square kilometers protected. Some small provinces, though, are well protected. Eight provinces have less than 1,000 square kilometers protected but more than five protected areas.

This rough assessment of the state of protection of the world's biotic regions reveals that a number of provinces are poorly protected and thus require attention. Of course, the fragility of the biome type, its species richness, and the threats to it must also be considered in any decision to protect an area.

The main concerns at the 1982 World Congress on National Parks (66) were to identify gaps in protected area coverage, and to develop effective management and support for existing protectorates. The Congress made recommendations, in the Bali Action Plan. These prompted the IUCN and the World Wildlife Fund (WWF) to help protected-area managers and others develop regional plans for the Indomalayan, Afrotropical, and Neotropical Realms. The regional plans, which will be updated every six years, list candidate sites for the protected area system, species needing attention in particular areas, and national and international initiatives needed for existing protected areas.

Although the Udvârdy classification of biogeographical provinces is a valuable tool at the global scale, finer-grained classifications are needed to adequately protect the many ecological types within or spreading across province boundaries. Badly needed national and regional efforts are now underway. The Wildlife Institute of India, for instance, has designed an Indian biogeographical classification to inventory its protected area coverage (67). Similar national or regional analyses, in much greater detail, have been devised for New Zealand, Australia, Peru, Costa Rica, the United States, and several other countries. The best analyses are those in which several sets of data were used to determine conservation priorities. In Brazil, for example, over 30 mapped sets of biological information were combined to determine the best areas to establish new parks and reserves. While this system needs refining, it shows a new level of sophistication in determining ways a nation can best conserve its biological heritage.

The ecosystem approach to assessing protected area coverage does not necessarily protect all species. Planners must also make species cross-checks. Thus, when a given type of environment is being considered for protection, the areas chosen should ideally include the rarest species of the region. For example, among remaining Javan swampy lowland forests, the most valuable choice would be the forest area containing the few remaining Javan rhinoceroses.

The Corbett Action Plan for the Indomalayan Realm assesses the adequacy of protected area coverage from several viewpoints (68). At the national level, the Plan calls for a map of the major habitats and their faunal communities and inventories of key species in each biogeographic unit and protected area. The Plan suggests that this information form the basis for new management priorities and plans for expansion. At the international level, the Plan recommends that IUCN review protected areas within the Indomalayan Realm and create a data base on the Realm. The Plan urges governments to collaborate on a biogeographical classification system for use throughout the Realm.

Managing Protected Areas

If all the desired maps and inventories could be made, scientists still would not know how much of any given ecosystem could assure its survival and that of its species. The 10-percent target suggested in IUCN's Bali Action Plan can be misleading and does not allow for the great variation in species richness from one part of the world to another. Some experts, therefore, have recommended

Figure 6.3 Realms, Biomes, and Biogeographical Provinces of the World

Realms and Biogeographical Provinces

Use of ***bold face italics*** indicates provinces with no protected areas. Use of *italics* only indicates provinces with five or fewer protected areas and where less than 1,000 km^2 are protected.

THE NEARCTIC REALM

1. Sitkan
2. Oregonian
3. Yukon taiga
4. Canadian taiga
5. Eastern forest
6. Austroriparian
7. Californian
8. Sonoran
9. Chihuahuan
10. Tamaulipan
11. Great Basin
12. Aleutian Islands
13. Alaskan tundra
14. Canadian tundra
15. Arctic Archipelago
16. Greenland tundra
17. Arctic desert and ice cap
18. Grasslands
19. Rocky Mountains
20. Sierra-Cascade
21. Madrean-Cordilleran
22. Great Lakes

THE PALEARCTIC REALM

1. Chinese Subtropical Forest
2. Japanese Evergreen Forest
3. West Eurasian Taiga
4. East Siberian Taiga
5. Icelandian
6. Subarctic Birchwoods
7. Kamchatkan
8. British Islands
9. Atlantic
10. Boreonemoral
11. Middle European Forest
12. Pannonian
13. West Anatolian
14. Manchu-Japanese Mixed Forest
15. Oriental Deciduous Forest
16. Iberian Highlands
17. Mediterranean Sclerophyll
18. Sahara
19. Arabian Desert
20. Anatolian-Iranian Desert
21. Turanian
22. Takla-Makam-Gobi Desert
23. Tibetan
24. Iranian Desert
25. Arctic Desert
26. Higharctic Tundra
27. Lowarctic Tundra
28. Atlas Steppe
29. Pontian Steppe
30. Mongolian-Manchurian Steppe
31. Scottish Highlands
32. Central European Highlands
33. Balkan Highlands
34. Caucaso-Iranian Highlands
35. Altai Highlands
36. Pamir-Tian-Shan Highlands
37. Hindu Kush Highlands
38. Himalayan Highlands
39. Szechwan Highlands
40. Macronesian Islands
41. Ryukyu Islands
42. Lake Ladoga
43. Aral Sea
44. Lake Baikal

THE AFROTROPICAL REALM

1. Guinean Rain Forest
2. Congo Rain Forest
3. Malagasy Rain Forest
4. West African Woodland/savanna
5. East African Woodland/savanna
6. Congo Woodland/savanna
7. Miombo Woodland/savanna
8. South African Woodland/savanna
9. Malagasy Woodland/savanna
10. Malagasy Thorn Forest
11. Cape Sclerophyll
12. Western Sahel
13. Eastern Sahel
14. Somalian
15. Namib
16. Kalahari
17. Karroo
18. Ethiopian Highlands
19. Guinean Highlands
20. Central African Highlands
21. East African Highlands
22. South African Highlands
23. Ascension and St. Helena Islands
24. Comores Islands and Aldabra
25. Mascarene Islands
26. Lake Turkana (Rudolf)
27. Lake Ukerewe (Victoria)
28. Lake Tanganyika
29. Lake Malaw (Nyasa)

THE INDOMALAYAN REALM

1. Malabar Rainforest
2. Ceylonese Rainforest
3. Bengalian Rainforest
4. Burman Rainforest
5. Indochinese Rainforest
6. South Chinese Rainforest
7. Malayan Rainforest
8. Indus-Ganges Monsoon Forest
9. Burma Monsoon Forest
10. Thailandian Monsoon Forest
11. Mahanadian
12. Coromandel
13. Ceylonese Monsoon Forest
14. Deccan Thorn Forest
15. Thar Desert
16. Seychelles and Amirantes Islands
17. Laccadive Islands
18. Maldives and Chagos Islands
19. Cocos-Keeling and Christmas Islands
20. Andaman and Nicobar Islands
21. Sumatra
22. Java
23. Lesser Sunda Islands
24. Celebes
25. Kalimantan (Borneo)
26. Philippines
27. Taiwan

THE OCEANIAN REALM

1. Papuan
2. Micronesian
3. Hawaiian
4. Southeastern Polynesian
5. Central Polynesian
6. New Caledonian
7. East Melanesian

THE AUSTRALIAN REALM

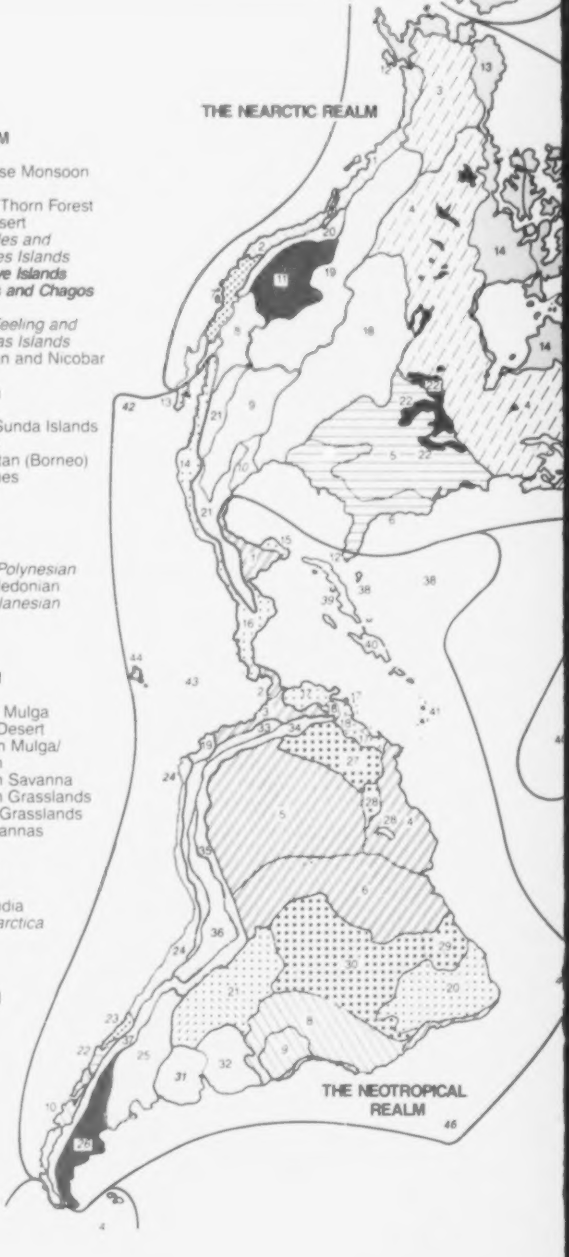
1. Queensland Coastal
2. Tasmanian
3. Northern Coastal
4. Western Sclerophyll
5. Southern Sclerophyll
6. Eastern Sclerophyll
7. Brigalow
8. Western Mulga
9. Central Desert
10. Southern Mulga/Saltbush
11. Northern Savanna
12. Northern Grasslands
13. Eastern Grasslands and Savannas

THE ANTARCTIC REALM

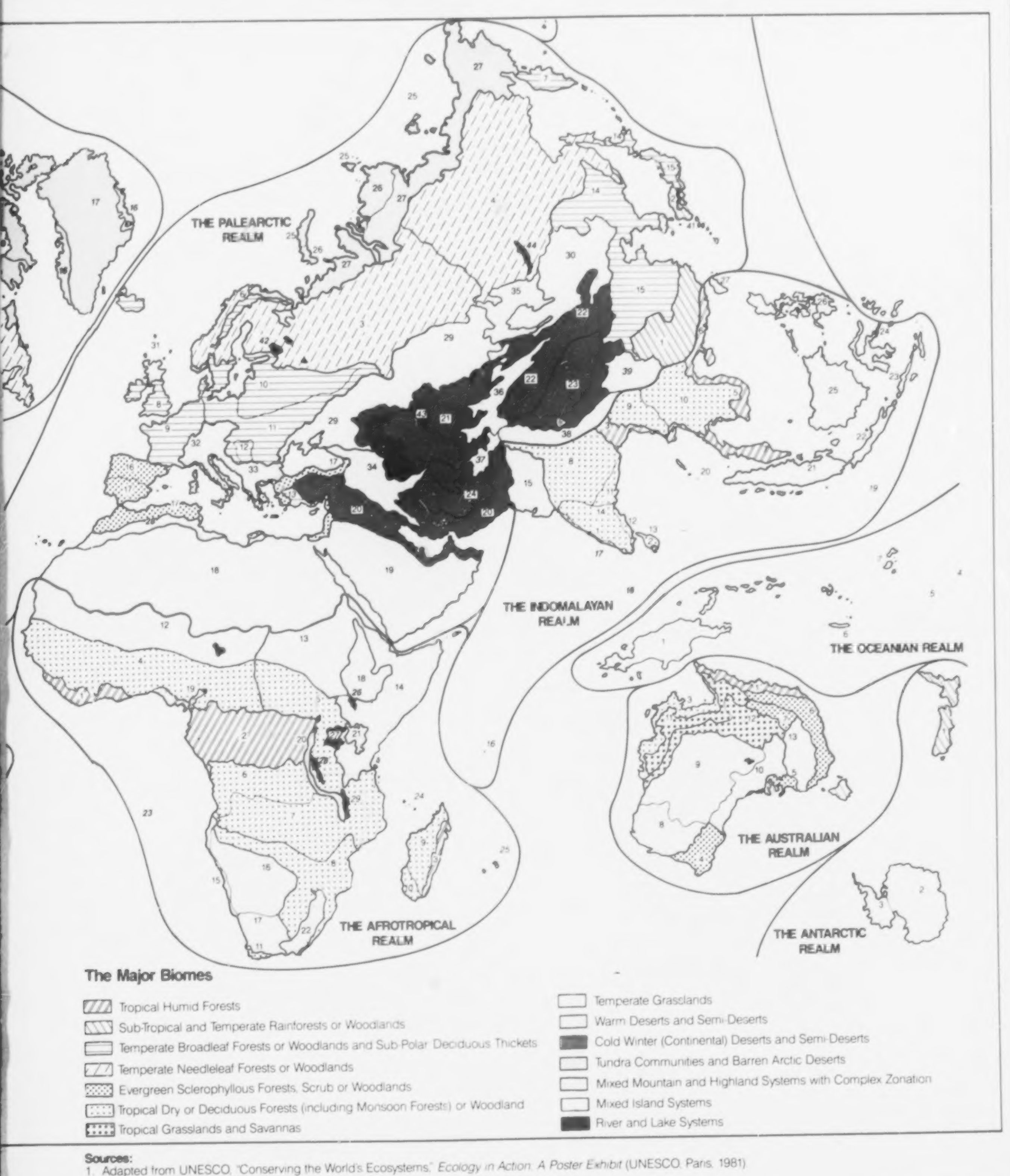
1. Neozealandia
2. Maudlandia
3. Marielandia
4. Insulantarctica

THE NEOTROPICAL REALM

1. Campechean
2. Panamanian
3. Colombian Coastal
4. Guyanan
5. Amazonian
6. Madeiran
7. Serra do mar
8. Brazilian Rain Forest
9. Brazilian Planalto
10. Valdivian Forest
11. Chilean Nothofagus
12. Everglades
13. Sinaloan
14. Guerreran
15. Yucatecan
16. Central American
17. Venezuelan Dry Forest
18. Venezuelan Deciduous Forest
19. Equadorian Dry Forest
20. Caatinga
21. Gran Chaco
22. Chilean Araucaria Forest
23. Chilean Sclerophyll
24. Pacific Desert
25. Monte
26. Patagonian
27. Llanos
28. Campos Limpos
29. Babacu
30. Campos Cerrados
31. Argentinian Pampas
32. Uruguayan Pampas
33. Northern Andean
34. Colombian Montane
35. Yungas
36. Puna
37. Southern Andean
38. Bahamas-Bermudan
39. Cuban
40. Greater Antillean
41. Lesser Antillean
42. Revilla Gigedo Island
43. Cocos Island
44. Galapagos Islands
45. Fernando de Noronja Island
46. South Trinidade Island
47. Lake Titicaca



Note. This map is based on work by M.D.F. Udvardy to define geographical units for conservation purposes, thus combining the distribution of species by realms with the distribution of ecosystems. Delimitation on a map of this scale inevitably involves gross generalization. No judgment is made on the percentage of each of the provinces protected.


THE PALEARCTIC REALM
THE INDOMALAYAN REALM
THE OCEANIAN REALM
THE AFROTROPICAL REALM
THE AUSTRALIAN REALM
THE ANTARCTIC REALM
The Major Biomes
▨ Tropical Humid Forests
▧ Sub-Tropical and Temperate Rainforests or Woodlands
☰ Temperate Broadleaf Forests or Woodlands and Sub-Polar Deciduous Thickets
▨ Temperate Needleleaf Forests or Woodlands
▒ Evergreen Sclerophyllous Forests, Scrub or Woodlands
░ Tropical Dry or Deciduous Forests (including Monsoon Forests) or Woodland
▦ Tropical Grasslands and Savannas
☐ Temperate Grasslands
☐ Warm Deserts and Semi-Deserts
■ Cold Winter (Continental) Deserts and Semi-Deserts
☐ Tundra Communities and Barren Arctic Deserts
☐ Mixed Mountain and Highland Systems with Complex Zonation
☐ Mixed Island Systems
■ River and Lake Systems

Sources:
1. Adapted from UNESCO, "Conserving the World's Ecosystems," *Ecology in Action: A Poster Exhibit* (UNESCO, Paris, 1981).
2. IUCN, 1985, Reference 63.

Table 6.6 Protected Areas in South America, 1985

Country	Size of Country (km^2)	Population (1985 est.)	No. of Protected Areas	Total Area Protected (hectares)	Percent of Country	Hectares Protected per 1,000 People
Argentina	2,776,643	30,564,000	29	2,594,351	0.93	85
Bolivia	1,098,575	6,371,000	12	4,707,690	4.29	739
Brazil	8,511,968	135,564,000	50	11,894,302	1.40	88
Chile	756,943	12,074,000	64	12,737,360	16.83	1,055
Colombia	1,138,907	28,714,000	30	3,958,750	3.48	138
Ecuador	455,502	9,380,000	12	2,627,365	5.77	280
French Guiana	90,000	73,000	0	0	0.00	0
Guyana	214,969	953,000	1	11,655	0.05	12
Paraguay	406,750	3,681,000	9	1,120,538	2.75	304
Peru	1,285,215	19,698,000	11	2,407,642	1.87	122
Suriname	163,820	353,000	9	582,400	3.56	1,650
Uruguay	186,925	3,012,000	6	28,778	0.15	10
Venezuela	912,047	18,386,000	34	7,388,912	8.10	402
Total	**17,998,264**	**268,823,000**	**267**	**50,059,743**	**3.78**[a]	**186**[b]

Notes:
a. Mean percentage for all countries' total area.
b. Mean number of hectares protected for total population of all countries.
Source: Adapted from International Union for Conservation of Nature and Natural Resources, 1985, Reference 62.

Table 6.7 Protected Areas by Biome and Realm, 1985

Biome and Realm	Number of Areas	Total Area (hectares)
Tropical Humid Forests		
Afrotropical	44	8,905,733
Indomalayan	122	5,092,774
Australian	53	7,776,347
Neotropical	61	17,277,197
Total	280	39,052,051
Subtropical/Temperate Rainforests/Woodlands		
Nearctic	18	8,129,505
Palaearctic	48	1,742,994
Australian	26	904,976
Antarctic	145	2,783,281
Neotropical	38	8,848,838
Total	275	22,409,594
Temperate Needle-Leaf Forests/Woodlands		
Nearctic	53	30,321,679
Palaearctic	122	8,463,690
Total	175	38,785,369
Tropical Dry Forests/Woodlands		
Afrotropical	240	48,673,552
Indomalayan	238	10,420,406
Australian	10	934,272
Neotropical	93	5,501,447
Total	581	65,529,677
Temperate Broad-Leaf Forests		
Nearctic	82	1,890,216
Palaearctic	400	9,631,346
Neotropical	1	5,415
Total	483	11,526,977
Evergreen Sclerophyllous Forests		
Nearctic	6	52,010
Palaearctic	122	3,374,156
Afrotropical	41	1,620,967
Australian	301	6,918,823
Neotropical	5	38,795
Total	475	12,004,751
Warm Deserts/Semi-Deserts		
Nearctic	22	3,962,948
Palaearctic	7	616,534
Afrotropical	57	23,783,085
Indomalayan	35	1,628,854
Australian	33	10,165,383
Neotropical	7	1,446,751
Total	161	41,603,555
Cold-Winter Deserts		
Nearctic	15	657,128
Palaearctic	57	12,854,167
Neotropical	4	36,700
Total	76	13,547,995
Tundra Communities		
Nearctic	20	107,924,951
Palaearctic	8	7,247,904
Antarctic	11	258,334
Total	39	115,431,189
Tropical Grasslands/Savannas		
Australian	12	2,041,393
Neotropical	18	7,011,403
Total	30	9,052,796
Temperate Grasslands		
Nearctic	25	387,751
Palaearctic	22	805,408
Australian	34	670,163
Neotropical	9	70,516
Total	90	1,933,838
Mixed Mountain Systems		
Nearctic	81	8,321,078
Palaearctic	231	8,071,815
Afrotropical	38	5,104,626
Neotropical	86	11,037,282
Total	436	32,534,801
Mixed Island Systems		
Palaearctic	9	52,142
Afrotropical	4	23,033
Indomalayan	177	10,426,372
Oceanian	51	4,108,584
Neotropical	26	1,190,599
Total	267	15,800,730
Lake Systems		
Nearctic	7	444,713
Palaearctic	1	18,300
Afrotropical	2	55,100
Neotropical	0	0
Total	10	518,113
Biogeographical Classification Unknown	132	7,866,578
Total	**3,510**	**427,598,014**

Source: International Union for Conservation of Nature and Natural Resources (IUCN), 1985, Reference 62.

20 percent or more for some biomes, such as tropical forests (69).

As for how large individual protected areas must be to maintain the species within them, the theory of island biogeography suggests that no reduced area, however well protected, can ultimately retain all its original species when surrounded by other land uses. But the larger the reserve, the slower and less severe the species loss will be. In crude terms, a single reserve containing 10 percent of the original area may support just 50 percent of the original species present. A study of 19 nature reserves in East Africa concluded that, in the absence of active management such as reintroductions, even the largest reserves would lose most of their large species within a few centuries (70).

An interesting 20-year experiment on "minimum critical area" of reserves is under way in the Brazilian Amazon north of Manaus. Here, the Brazilian government and the World Wildlife Fund are trying to determine how wildlife survives in forest reserves of different size—from 1 to 1,000 hectares—that are surrounded by agricultural land. Already it is obvious that species diversity in the very small plots deteriorates rapidly and such plots are almost worthless as reserves. It will take at least 20 years to gauge the success of the bigger reserves (71). Given the rapid cutting of tropical forests, however, most conservationists recommend establishing many large reserves now.

If adequate protected-area coverage is achieved, proper management will be the key to success. Today, management is excellent in some countries and negligible in others. Some national parks are overrun with farmers, hunters, and timber-cutters. Accordingly, many of the recommendations of the Bali Action Plan and regional action plans call for better training of managers, strengthened management policy and government conservation agencies, and the creation of management plans for individual reserves.

Many recent studies of wildlife conservation call for increased support for biological data centers. IUCN's Conservation Monitoring Center in Cambridge, England, is a principal focal point for this kind of information, though its budget is limited. More local or national data bases are needed, such as those being developed by several Latin American countries.

One category of protected area—the Biosphere Reserve—can potentially serve nearly the whole range of functions of IUCN's ten categories. Ideally, these reserves consist of core areas that receive strict protection, and other zones in which people live and work, usually in farming and forestry. In these reserves, research on both undisturbed and exploited ecosystems is conducted along with environmental education, training, and international scientific exchanges. As of early 1985, 243 biosphere reserves had been established in 65 countries (72).

Biosphere reserves are an important element in UNESCO's Man and the Biosphere Program (MAB), which adopted an Action Plan for Biosphere Reserves in December 1984. This plan contains 35 recommendations to be carried out by governments and international organizations, mostly from 1985 to 1989. The actions would expand the reserve network, improve research conducted within reserves, and improve management of the reserves so that they serve all intended purposes. If all these actions are carried out, biosphere reserves might become the most important component of the world's protected-area system.

RECENT DEVELOPMENTS

U.S. STRATEGY ON BIOLOGICAL DIVERSITY

Conservationists around the world are concerned about the rapid loss of biological diversity in the tropics. But tropical countries themselves lack adequate resources to handle the problem, so help from other countries is essential. Recognizing its major role in foreign assistance, the U.S. Government sponsored its first international conference on biological diversity in November 1981 to evaluate the world's wildlife conservation efforts.

In 1983, the U.S. Congress amended the Foreign Assistance Act of 1961, giving the government a legal mandate to help developing countries conserve their genetic resources. The amendments were known collectively as the International Environment Protection Act of 1983. It directed federal agencies to draft a comprehensive government strategy for conserving biological diversity in the Third World. Over the next year, a task force of 12 government agencies, chaired by the U.S. Agency for International Development (U.S. AID), consulted with experts from government, industry, academia, and environmental and policy groups. The resulting *U.S. Strategy on the Conservation of Biological Diversity* (73), submitted to Congress in February 1985, makes U.S. development assistance programs the focus of the government's plan. It calls for U.S. AID and the multilateral development banks to change the way they review the environmental impacts of their projects and to refuse to fund projects that destroy key ecosystems. The 67 public and private actions recommended in the interagency document include policy changes, support for education, institution strengthening, more research, and better management of protected areas. Critics have objected that the actions proposed appear as options rather than programs with funding: that the government presented a study, not a strategy as Congress requested. Currently, U.S. AID is preparing a detailed plan for directing its own activities.

Meanwhile, legislation has been introduced in the U.S. Congress "to amend the Foreign Assistance Act of 1961 to protect biological diversity in developing countries." Among major provisions are the allocation of $10 million annually to be used directly for conserving biological diversity, much of it through U.S. AID. U.S. AID is directed to help developing countries survey and protect critical ecosystems and establish and maintain protected areas, working whenever possible with private and voluntary organizations that would receive at least $3 million of the $10 million allocated.

Closely related and parallel to the biological diversity effort is a government initiative on tropical forests. Legislation recently introduced in Congress directs the U.S. Government to put more dollars into forest conservation projects worldwide. The initiative also earmarks government money for non-governmental conservation organizations.

NATIONAL CONSERVATION STRATEGIES

In the late 1970s, IUCN, UNEP, and WWF developed a global strategy for conserving the world's biological resources. Their 1980 report, *The World Conservation Strategy: Living Resource Conservation for Sustainable Development* (74), links conservation with successful development and emphasizes priorities for national action, including the formulation of national conservation strategies. Currently, some 40 countries have started or completed such national strategies, including Australia, Malaysia, Nepal, Senegal, Zambia, Madagascar, Italy, Norway, the United Kingdom, and Belize. Wildlife conservation is an important element in these strategies.

The national strategies necessarily have varied widely in how they were developed, which institutions were involved, and how closely a particular strategy was linked to other national efforts such as economic development plans. In about half of the countries, participation in preparing a national conservation strategy has been broad, including representatives of government, business, academia, conservation organizations, and other sectors. The rest typically involve only a few government officials. In many countries, public understanding of wildlife and other resource issues has increased dramatically. Nigeria, for example, whose prior conservation activity had been small and local, assembled some 400 people from all over the country to discuss the national conservation strategy and launch a draft document.

In June 1986, an international conference on conservation and development will bring 300 decisionmakers and professionals to Ottawa, Canada, to review the success and effectiveness of *The World Conservation Strategy* and the national strategies already written or now being developed. Conferees will also discuss the most effective ways to develop and implement national strategies and how these efforts can better integrate conservation and development.

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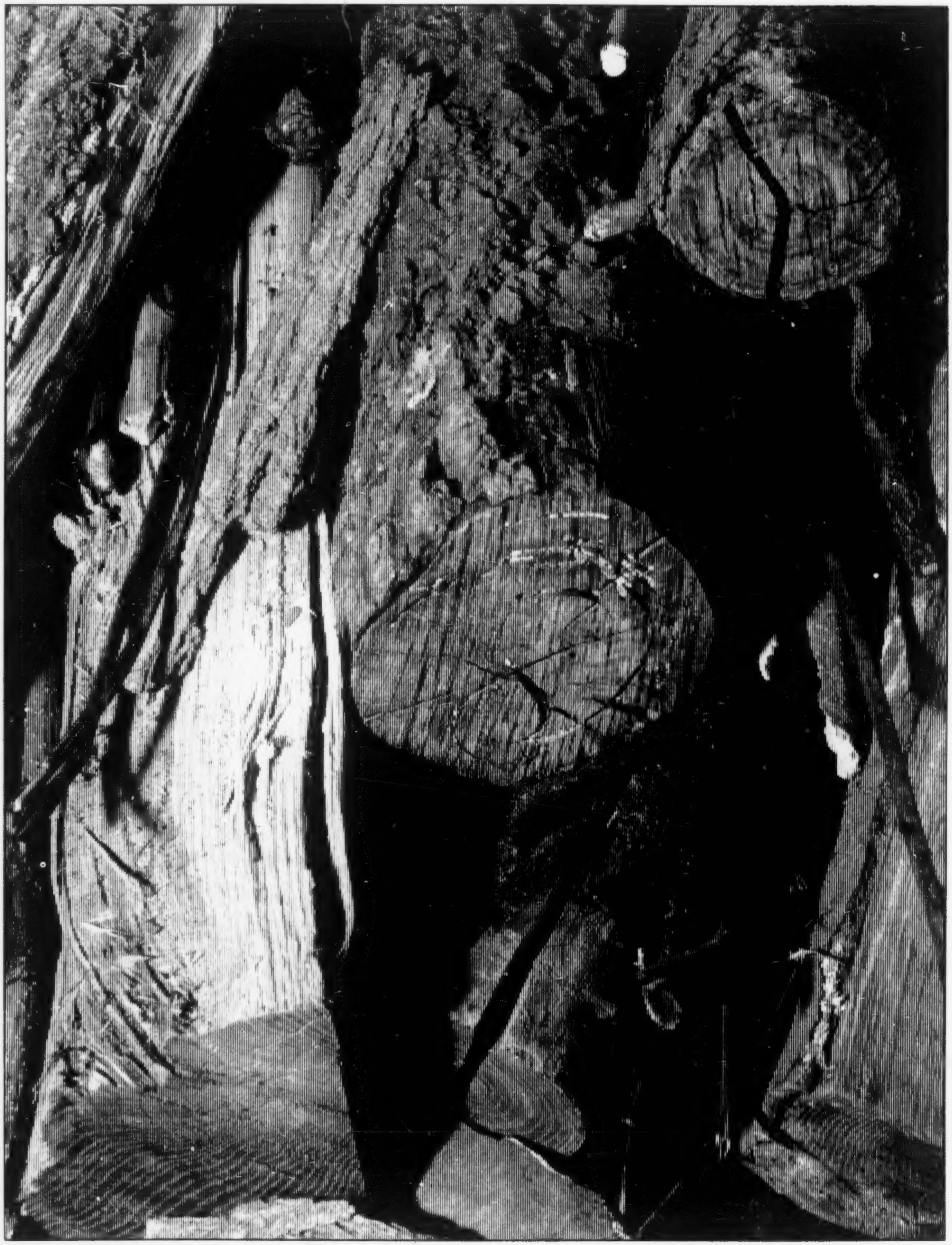


7. Energy

Energy is sometimes referred to as the lifeblood of our societies, for fuels are used to drive virtually all human activities. In the industrialized world commercial fuels—fuels that are traded commercially—dominate the energy scene. Fossil fuels—oil, gas, and coal—account for about 90 percent of global commercial energy requirements, and of these oil is the most important (1).

By contrast, in the Third World a combination of commercial and non-commercial woodfuels (that is, firewood and charcoal) and other biofuels (animal and crop residues) are the main source of energy for some 2.5 billion people, or roughly half the world's population (2). At the global level, more people depend on wood than on any other single energy source for their daily energy needs. The Director General of the U.N. Food and Agriculture Organization (FAO) has pointed out that "In this respect, wood can still be counted the world's most important fuel" (3).

CONDITIONS AND TRENDS

In 1984, commercial (4) energy consumption throughout the world totaled 7,201.6 million metric tons of oil equivalent (Mtoe). (See Table 7.1.) (One toe contains the same energy as about 7.33 barrels of crude oil.) The two biggest consumers of all this energy are the United States (25 percent) and the Soviet Union (18.4 percent). On a per capita basis, Canada is the biggest consumer at 8.8 toe per person, followed by the United States (7.8 toe), the USSR (4.8 toe), Eastern Europe (4.1 toe), and Western Europe (about 3.4 toe). In contrast, the developing countries use only about 0.5 toe per person (5).

There was a steady and rapid growth in world energy consumption after World War II—for almost three decades—as economies prospered on cheap and plentiful supplies of oil. During the last 10–15 years, however, this trend has been disrupted, as Figure 7.1 shows, and the picture has become more complicated and less predictable.

PATTERNS AND TRENDS IN ENERGY CONSUMPTION AND PRODUCTION

Policies and patterns of consumption have changed dramatically, primarily in response to the oil price rises of 1973–74 and 1979–80. As a result, energy systems based on renewable sources have received increased attention in both the developed and developing worlds. The only renewables making a significant contribution at present are biomass and hydropower, but important advances have been made with wind energy conversion systems (WECS), solar collectors, and photovoltaic systems, which will be examined in detail in a later edition of *World Resources*.

There are marked differences in the patterns and trends of energy consumption among different groups of

Table 7.1 Commercial Energy Consumption by Region, Key Countries, and Fuels, 1984
(million metric tons of oil equivalent)

	Oil	Natural Gas	Coal	Hydro-electric	Nuclear	Total	Percent
North America	791.4	505.8	466.2	154.6	101.3	2019.3	28.0
Western Europe[a]	591.0	190.1	256.7	107.0	104.6	1249.4	17.4
Oceania[b]	35.5	14.4	34.6	9.3		93.8	1.3
Japan	214.6	33.1	64.0	19.8	30.6	362.1	5.0
USSR	447.8	439.4	357.0	53.0	25.0	1322.2	18.4
Eastern Europe[c]	98.7	77.0	274.2	7.2	7.5	464.6	6.5
Developing Countries[d]	579.7	139.3	260.4	111.0	13.2	1103.6	15.3
China	85.8	10.8	466.5	23.5	0.0	586.6	8.1
World Total	**2844.5**	**1409.9**	**2179.6**	**485.4**	**282.2**	**7201.6**	**100.0**
Percent	39.5	19.6	30.3	6.7	3.9	100.0	

Notes:

a Western Europe includes Austria, Belgium, Cyprus, Denmark, Federal Republic of Germany, Finland, France, Gibraltar, Greece, Iceland, Republic of Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Yugoslavia.

b **Oceania** includes Australia, New Zealand, Papua New Guinea, Southwest Pacific Islands.

c Eastern Europe includes Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania.

d Developing Countries includes all Latin American, African (including South Africa), South Asian, Southeast Asian, and Middle Eastern countries.

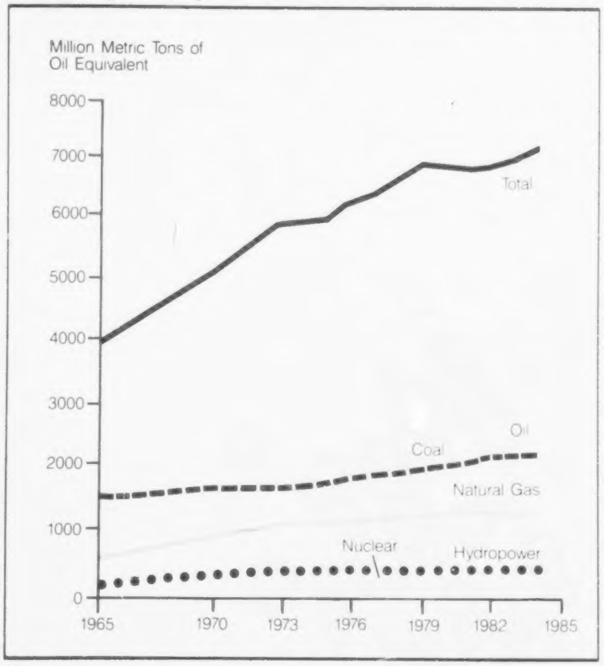
Source: British Petroleum, 1985, Reference 1.

countries, as well as in the specific energy issues that face them. Key developments in different regions are highlighted below.

Western Industrialized Countries

The Western industrialized countries include: Western Europe, North America, Japan, Australia, and New Zealand. Total primary energy consumption in Western Europe and North America has changed in strikingly similar ways during the last 20 years, as Figure 7.2 shows. In both regions there was a decline in consumption after the oil price rises in 1973–74 and 1979–80. As a result, the 1984 level of consumption for each of these regions was similar to what it had been ten years before.

Figure 7.1 Global Commercial Primary Energy Consumption by Fuel, 1965-84



Sources:
1 British Petroleum, 1985, Reference 1.
2 British Petroleum, 1985 (personal communication).

Eastern Europe and the Soviet Union

This group of countries includes the Soviet Union and the Eastern European countries of Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, and Romania. There are significant differences between the energy situation in the Soviet Union and Eastern Europe, but their close economic and political ties mean that they do function as a distinct regional grouping in energy terms. A key energy development for these countries in recent years has been the stagnation of Soviet oil production. This is critically important to Eastern Europe as well as to the Soviet Union itself because the Eastern European countries, with the exception of Romania, depend on the Soviet Union for about 90 percent of their oil.

Eastern Europe's increasing demand for oil, combined with the Soviet Union's constrained supply, is expected to make energy trade "the most important and problematic aspect of Soviet-East European economic relations in the second half of this decade" (6). The Eastern European dependence on Soviet energy supplies seems likely to escalate, binding these countries closer to the USSR in economic terms.

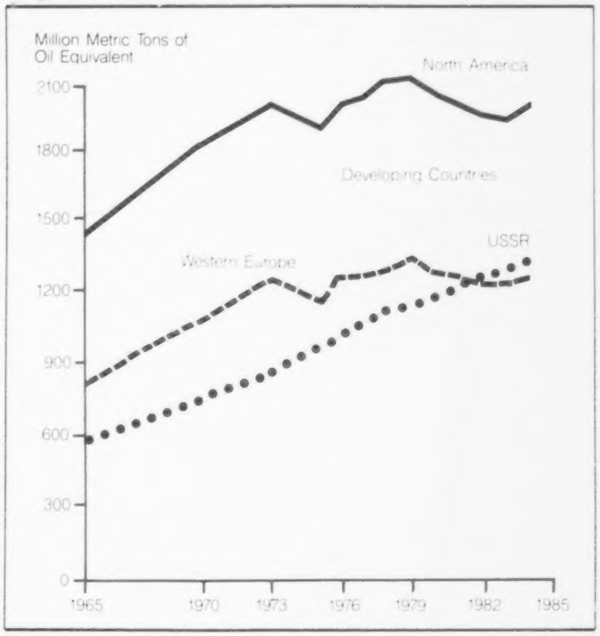
Given the constraints on Soviet fuel production (problems have been encountered in increasing the contribution of coal and nuclear power as well as oil), improved energy efficiency is an obvious priority. However, as Figure 7.2 shows, Soviet energy consumption has been increasing steadily, in contrast to the trend in the West, due in part to lower fuel prices in the USSR.

Developing Countries

As in the Soviet Union, commercial energy consumption in the developing world has risen during the last two decades, despite the oil price shocks. And it is expected to continue to rise because of the comparatively low level of per capita consumption in these countries and the likelihood of further major increases in population.

During the last decade, oil-importing developing countries have felt the impact of two energy crises

Figure 7.2 Primary Energy Consumption by Region, 1965-84



Sources:
1. British Petroleum 1985 Reference 1
2. British Petroleum 1985 (personal communication)

simultaneously. For the last few years, the increased price of oil has proved a severe burden to their economies, particularly with non-oil commodity prices remaining fairly constant (see Figure 7.3). In 1981, low- and middle-income oil-importing countries were spending 61 percent and 37 percent, respectively, of their export earnings on oil imports (7); the international debts of these countries increased by a factor of six between 1973 and 1982 (8). At the same time most of these countries have been experiencing a serious decline in the availability of their principal domestic source of energy—fuelwood. (See "Focus on: Fuelwood Scarcity," below.)

OIL

In 1984, oil still accounted for 40 percent of total commercial energy consumption (9). Nevertheless, this figure is lower than the 47.4 percent share which oil held in 1973 (10). The drop was due, in part, to the economic recessions following the oil price rises since 1973 (see Figure 7.4), partly to improvements in the efficiency with which oil is used, and partly to the substitution of other fuels for oil.

Although oil prices have recently been declining in dollar terms—as an internationally traded commodity, oil is priced in U.S. dollars—the recent strength of the dollar relative to other currencies means that for Western Europe and the developing countries the price of oil has remained high.

During the last 20 years, there have been major changes in the share of oil consumption among the First, Second, and Third Worlds, as is clear from Table 7.2.

Western Industrialized Countries

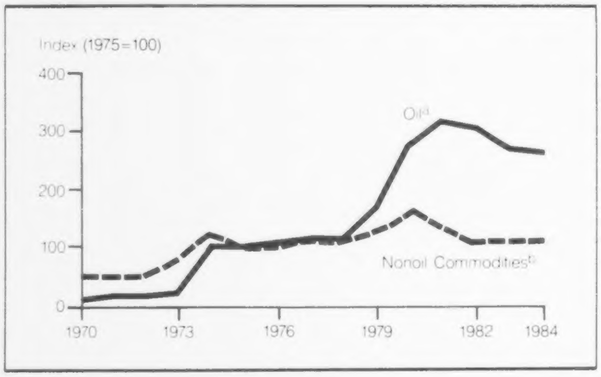
The share of oil in total energy consumption of International Energy Agency (IEA) member countries (11) dropped from 51 percent in 1973 to 43 percent in 1983, and their oil intensity (total oil consumption divided by Gross Domestic Product [GDP]) fell by 30.4 percent over the same period.

About 20 percent of the oil consumed by the Organization for Economic Cooperation and Development (OECD) countries in 1982 (12) was used in the residential sector (13), 18.7 percent in industry, 53.2 percent in transport, and the remainder in the service sector and agriculture (14). The proportion of oil used in the residential and industrial sectors has declined considerably since the first OPEC price rises, primarily because of energy efficiency improvements and fuel substitution.

In the *residential* sector, oil use declined by about 30 percent between 1972–73 and 1982 (15). It appears that 40–45 percent of the reduction resulted from fuel conversions away from oil or investments in efficiency measures, all of which would continue for a long time even if oil prices fall, while the remainder arose from rapid—and reversible—cutbacks in consumption in response to the price increases (16).

Total final oil consumption by *industry* in the IEA countries fell by 27 percent in this period (1973–82) (17). Considerable fuel substitution (from oil to coal) has taken place in the energy-intensive industries—notably iron and steel and cement—which were able to switch fuels relatively easily (18). Oil substitutions also occurred in another energy-intensive industry, paper and pulp, which increased its use of biomass (wood wastes and tree

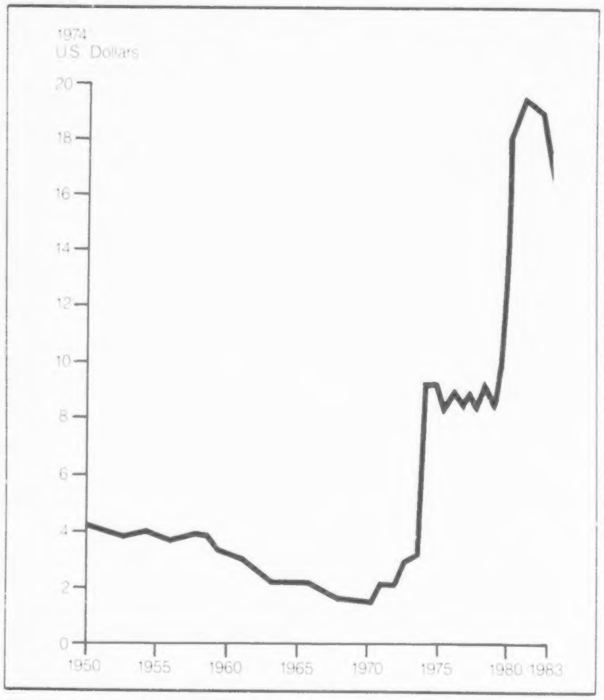
Figure 7.3 Oil and Nonoil Commodity Prices, 1970-84



Notes:
a. Average dollar price of internationally traded oil.
b. Average dollar price of 33 primary commodities weighted by each commodity's share in developing countries' exports.

Source: The World Bank, *The World Bank Annual Report 1985* (The World Bank, Washington, D.C., 1985), p. 40.

Figure 7.4 Price of Oil (Saudi Arabian Light Crude), 1950-83



Source: P. Odell, *Draining the World of Energy* (Center for International Energy Studies, Rotterdam, 1984) p. 8

stumps), particularly in North America and Scandinavia and in some cases switched from oil to coal (19).

More than half the total oil consumption is accounted for by the *transport* sector, whose share has grown during the last decade or so. During the last ten years, oil has constituted 99 percent of the fuels consumed for transport purposes in the western industrialized countries. Road transport has accounted for almost 80 percent of this oil consumption; air transport is the other major user.

The impact of the oil price hikes was felt in this sector also (see Table 7.3), so that although transport's share of total oil consumption increased, the absolute level of consumption fell.

Table 7.2 Oil Consumption by Region and Percent of World Consumption, 1973 and 1984

(million metric tons of oil equivalent)

	1973	Percent	1984	Percent
North America	901.7	69.9	791.4	57.4
Western Europe	748.9		591.0	
Japan	269.1		214.6	
Oceania	34.8		35.5	
Soviet Union	325.7	14.3	447.8	19.2
Eastern Europe	75.1		98.7	
Developing Countries (including China)	442.7	15.8	665.5	23.4
World Total	**2,798.0**	**100**	**2,844.5**	**100**

Source: British Petroleum, 1984 and 1985, Reference 1

Table 7.3 Oil Consumption in the Transport Sector in IEA Countries, 1973–82

(million metric tons of oil equivalent)

	1973	1975	1977	1978	1979	1980	1981	1982
Cars, Buses, & Trucks	516.4	527.9	586.0	620.7[a]	615.2	594.7	581.8	582.7
Total	697.4	697.7	757.8	801.8	806.5[a]	782.2	756.9	746.5

Note: a. Year of peak consumption.
Source: International Energy Agency (IEA), *Fuel Efficiency of Passenger Cars* (OECD, Paris, 1984), p. 24.

Considerable improvements have been made in the fuel efficiency of new cars, primarily through reductions in car weight and greater use of new fuel-efficient technologies. The change in oil consumption trends shown in Table 7.3 is also partly due to reductions in the average mileage driven per car. The combination of these factors resulted in a drop of 21.4 percent between 1973 and 1982 in the average petrol (gasoline) consumption per car in the IEA countries; however, this was offset by a 34.7 percent increase in the number of vehicles over the same period. Thus, the net result was an increase in petrol consumption of 5.9 percent between 1973 and 1982.

Eastern Europe and the Soviet Union

Oil consumption in the Soviet Union increased without interruption between 1965 and 1983. This increase was due in large measure to the Soviet Union's self-sufficiency in oil at the time; production rose from 429.0 Mtoe in 1973 to 616.3 Mtoe in 1983 (20). Consequently, when oil prices in the rest of the world quadrupled in 1973–74, prices in the Soviet Union were not affected. In the early 1980s, however, the rate at which oil production was increasing slowed markedly. In 1984, production fell for the first time since World War II as a result of production difficulties, especially in the new oil fields in Siberia, where output is hampered by extremes of climate and the high costs of oil extraction and long-distance transport. These problems lead many observers to doubt whether the Soviet Union will be able to increase oil production significantly above the current level (21).

Unlike the western industrialized countries, the Soviet Union has not needed to reduce its oil consumption because of dependency on foreign supplies. On the other hand, its oil exports are extremely important in foreign exchange terms. In 1983, about 64 percent (some $14 billion) of Soviet hard currency earnings came from oil sales. For this reason, it is clearly in the Soviet Union's economic and strategic interest to economize on its oil consumption.

An important element of Soviet policy has been to substitute natural gas for oil, but so far the impact on oil consumption has been limited. Electricity generation is one area in which the use of oil could be reduced. Oil's share of fuel use by power stations rose from 7.5 percent in 1960 to 35.2 percent in 1980, but recent policy shifts have given priority to reversing this trend (22).

Car ownership is very low in the Soviet Union compared with the West, and in 1980 there were only 8.5 million cars in use. Thus, there is the potential for a major increase in car ownership and a corresponding increase in oil use. Realizing this the Soviets have launched a major program aimed at building metros (subways) in all major cities, partly because this will discourage greater use of cars and partly because the metro is seen as the quickest, cleanest, and cheapest mode of urban transportation (23).

The oil situation in the Soviet Union has been significantly different from that in Eastern Europe, where oil consumption has declined slightly since 1980, from 102.6 to 98.7 Mtoe (24). This decline is probably because of the economic difficulties these countries have been experiencing and their lack of foreign exchange for purchasing oil either on the world market or from the Soviet Union.

Developing Countries

Third World oil consumption has increased markedly in the last 30 years or so, and between 1973 and 1984 the developing world's share of oil consumption rose by almost half. (See Table 7.2.) During the last five years, however, the absolute level of oil consumption barely increased at all as oil prices grew and economic growth rates fell well below those experienced in the 1970s.

Generally speaking, the main use of oil in developing countries is for transport, and the second most important sector is industry. In 1981, for example, the proportion of oil used for transport in India, Kenya, Sri Lanka, and Brazil ranged between 43.2 percent (Sri Lanka) and 56.2 percent (Brazil), while the proportion consumed by industry ranged between 25.2 percent (Brazil) and 30.6 percent (India) (25).

When economic activity increases again in the developing countries, oil consumption can be expected to resume its upward trend, particularly for transport purposes. The current low level of personal travel and vehicle ownership in the Third World allows ample room for expansion. In these countries, the growth of markets, especially the traffic in manufactured goods and trade items, is an essential element of the entire development process. However, in some countries, particularly those with sugar production such as Zambia, it may be practicable to use alcohol fuels from biomass instead of oil, as Brazil has done.

Global Prospects For Oil

With the present excess of supply capacity, and the increased contribution of non-OPEC countries, it appears that the threat of further oil supply disruptions or major price hikes has receded, at least for a few years. (See "Recent Developments," below). It is widely believed that the current downward trend in oil prices will continue during the next few years. Oil is not expected to return to its 1982 price level until some time during the 1990s. Exactly when prices will start to rise again—and the market tighten—depends to a large extent on the demand factors reviewed above.

On the supply side, overall production in the West, including the United States and the North Sea, is expected to decline steadily between now and the turn of the century; production in the Soviet Union is not likely to increase significantly and might even decline. It is generally expected, therefore, that before the turn of the century there will be a return to increased reliance on Middle East sources unless governments vigorously pursue policies to encourage fuel substitution, oil conservation, and indigenous oil exploration. The latter is particularly important in the Third World, where exploration efforts have lagged.

By the time the world's crude oil supplies have been depleted, the total amount of oil used is expected to range from 1.6 to 2.4 trillion barrels (26, 27, 28). If these estimates are correct, production could continue at about the present level until some point in the second quarter of the next century, but it would then fall off quite rapidly.

NATURAL GAS

Natural gas is the world's third largest commercial fuel (after oil and coal), accounting for 19.6 percent of global energy consumption in 1984 (29). This figure represents a slight increase over its 1973 share of 18 percent (30). North America (36 percent) and Eastern Europe and the Soviet Union (36.5 percent) consumed the largest amounts, with Western Europe (13.5 percent) and the developing countries (10.6 percent) consuming considerably smaller shares (31).

This global picture masks major regional changes that have been taking place during the last 10–15 years. Consumption in the United States declined from 562.5 Mtoe in 1973 to 458.0 Mtoe in 1984, resulting in a decline in production over the same period (32). Nevertheless, natural gas still accounted for 25 percent of U.S. energy consumption in 1984, three quarters of which was used in industry and the residential sector in roughly equal amounts (33).

The trend in the rest of the world has been in the opposite direction. Consumption increased by about 90 percent between 1973 and 1984, from 503.6 to 951.9 Mtoe (34). In the USSR, gas consumption more than doubled between 1973 and 1984, from 198.8 Mtoe to 439.4 Mtoe, amounting to one-third of Soviet energy consumption (35). The Soviet Union replaced the United States as the world's largest producer in 1983. In Western Europe consumption increased from 129.9 Mtoe in 1973 to 190.1 Mtoe in 1984. In the European OECD countries, industry consumes the largest share (43 percent); within this sector the chemical industry is the major user, as it is in the United States (36). Natural gas has been an important substitute for oil in the domestic and service sectors in most of these countries. Some European countries (the United Kingdom, Norway, and the Netherlands) have significant reserves of their own, but most others have to import gas.

The Soviet Union exports considerable quantities of natural gas to both Eastern and Western Europe. The importation and use of Soviet gas by Western Europe have generated much controversy within the NATO countries, centering around the implications these gas imports have on the long-term security of the Western Alliance (37).

In the Third World, natural gas is not an important fuel at present due to a lack of infrastructure and exploration; it constitutes less than 1 percent of the total commercial energy consumed. However, many developing countries—particularly in South and Southeast Asia—have indigenous gas reserves that, if developed, could be an important source of energy given the necessary distribution network.

At the end of 1984, proved reserves of natural gas (87,000 Mtoe) were slightly smaller than oil reserves (96,000 Mtoe) (38). However, since gas consumption is considerably less than oil consumption, the lifetime of the gas reserves at current levels of use (60 years) is almost twice that of oil reserves (34 years). Forty-three percent of proved gas reserves are in the USSR, 26 percent in the Middle East (particularly Iran), 8.5 percent in North America, 6.1 percent in Western Europe, 5.5 percent in Africa (3.2 percent in Algeria), and 4.9 percent in Asia and Australia (mainly in Indonesia and Malaysia) (39).

In the IEA countries as a whole, the current production level is likely to be maintained at least until the turn of the century. Production is expected to continue increasing in the Soviet Union for some time to come, and new fields will be opened up in many Third World countries. At the global level, therefore, it should be possible to maintain the current level of consumption for several decades.

Natural gas resources have not been as extensively investigated as oil resources. Until recently, gas has been found as a by-product of the search for crude oil; so far there has been little systematic prospecting for coal-based natural gas. In addition to conventional natural gas resources, which account for almost all the proved reserves, there are various kinds of "unconventional" resources. Most of the unconventional gas production is expected to take place in North America (40). Some types of unconventional sources—tight gas, Devonian shale, and coal seam methane—may play a significant role in U.S. gas supply within the next 20–30 years (41).

COAL

In the aftermath of the first oil price rises, Western Europe and North America began to look at coal as a possible replacement for imported oil. By 1984, however, coal's share of world energy consumption had increased only slightly above what it was in 1973, from 28.2 percent to 30.3 percent (42). Coal's contribution to the Soviet energy budget actually fell from 36 percent in 1973 to 27 percent in 1984, reflecting the fairly steady level of coal output and the increasing use of natural gas and oil (43). On the other hand, coal consumption in China increased by a remarkable 60 percent, making the People's Republic one of the three major producers of coal in the world, along with the United States and the Soviet Union (44). Together these three countries account (in roughly equal amounts) for about 60 percent of world production.

Domestic coal prices vary considerably from country to country, according to productivity levels, whether the coal is obtained from deep or surface (opencast) mines, the amount of government subsidy, etc. On the international market, world steam coal prices have been falling during the early 1980s—from $60 per metric ton in 1980 to about $45 per metric ton in late 1984 (both in 1982 dollars), as a result of lower than expected demand. Between now and the turn of the century, prices are not expected to rise much; they could even remain constant in real terms, partly because of new producer countries entering the market. International trade in coal is currently dominated by Australia, the United States, and South Africa, but new low-cost suppliers such as Colombia, Botswana, and Indonesia will gradually increase the diversity and competitiveness of the trade.

Like natural gas, coal requires a considerable infrastructure before it can be used on a significant scale, and partly for this reason coal's share of total primary energy consumption in developing countries tends to be less than in many industrialized countries. There are notable exceptions, however. Apart from China, coal is also the major fuel in India, accounting for 41 percent of all commercial energy consumption and 26 percent of total energy consumption (including non-commercial biomass fuels) in 1979 (45). Coal is expected to make an increasing contribution to power generation in the developing countries; its share of the fuel mix is projected by the World Bank to rise from 29.9 percent in 1980 to 35.6 percent in 1995 (46).

Coal is the major fuel used in electricity generation in the OECD countries, and in 1983 about two-thirds of all coal use was for this purpose. Of the remainder, three-quarters was consumed in the industrial sector, primarily by the iron and steel industry, with a significant amount in the residential sector as well (47). Further substitution of coal for oil can be expected in industry, but this is likely to be a slow process, and little substitution is expected in the transport or residential/service sectors in the foreseeable future.

Coal Supply Prospects

World coal deposits are vast—an order of magnitude greater than oil and gas resources—and it is unlikely that new discoveries will substantially alter the present estimate of 10 trillion (10^{13}) metric tons (48). If all this coal were recoverable, and consumption continued at present rates, several thousand years' supply would be available. Not surprisingly, therefore, the Western industrialized countries see coal as a substitute for oil (and to a lesser extent, natural gas). Such figures, however, give no indication of the amount of recoverable coal, allowing for technical and economic constraints.

A more meaningful assessment of the future availability of coal resources is provided by the data in Table 7.4, which show that there are 484 billion metric tons of coal that can be exploited within the next 20 years. This supply would last more than 100 years at the current rate of consumption. Thirty-seven percent of this coal is in the OECD countries (primarily the United States, which has 21 percent of the world's total), 23 percent is in the USSR, 19 percent in Asia (mostly China, 15 per-

Table 7.4 World Coal Resources and Reserves by Type of Coal

(billion metric tons)

	Bituminous Coal and Anthracite	Sub-bituminous Coal	Brown Coal/ Lignite
Proved Amount-in-Place 1[a]	920	260	340
Proved Recoverable Reserves 1[b]	515	166	265
Accessible Coal in Significant Coalfields 2[c]	358	25	101

Notes:

a. "Proved Amount-in-Place" is defined as the fraction of total resources that has been carefully measured and assessed as being exploitable in a particular country under present and expected local economic conditions with existing available mining technology.

b. "Proved Recoverable Reserves" represents the fraction of proved reserves (Amount-in-Place) that can be recovered (actually mined) under the same economic and technological limits as described above.

c. The category "Accessible Coal in Significant Coalfields" gives estimates of the amount of coal from particular coalfields that is considered capable of playing a significant part in world coal supply and trade within the next 20 years. Thus, it excludes, for example, virgin fields remote from ports, railways, and population centers.

Sources:

1. World Energy Conference (WEC), *Survey of Energy Resources* (WEC, London, 1983).
2. International Energy Agency (IEA) Coal Research, *Concise Guide to World Coalfields* (IEA, London, 1983).

cent), 8 percent in Poland, 6.5 percent in Africa (almost entirely South Africa), and 1.3 percent in Central and South America (mainly Colombia and Mexico). The fact that the United States, along with the OECD as a whole, have large reserve estimates is partly because these countries — in contrast to most developing nations — are well-explored and nearly all their resources have been identified. Such vast reserves of coal mean that its use is not likely to be limited by supply constraints. If coal does not increase its share of the market significantly, it will be due either to lack of infrastructure or to coal's environmental impacts. (See Box 7.1.)

PRIMARY ELECTRICITY

Fossil fuels generate the vast majority of the world's electricity, but since the 1960s there has been a gradual shift toward other sources of electricity. In the industrialized countries, nuclear power has been the preferred choice, at least until recently, while hydropower's contribution has been increasing steadily in the Third World.

Nuclear Power

Nuclear power's contribution has increased dramatically in recent years, from 62.4 Mtoe in 1974 to 282.2 Mtoe in 1984 (49). (See Part IV, Table 8.3.) In 1984, nuclear power accounted for 3.9 percent of world primary energy consumption and 16 percent of electricity produced in the OECD countries. More than 90 percent of nuclear electricity production is in highly industrialized countries, primarily in North America (35.9 percent) and Western Europe (37.1 percent) (50). The size of nuclear generating capacity in the countries with the largest nuclear power programs is shown in Table 7.5.

Table 7.5 Nuclear Power Plant Capacity in Key Countries, 1984

(gigawatts of electricity)

Belgium	3.5
France	33.3
Federal Republic of Germany	16.1
Spain	4.8
Sweden	8.4
United Kingdom	10.7
Western Europe Total	**83.8**
Canada	10.0
United States	71.2
Japan	21.8
Taiwan	4.0
USSR	24.1
World Total	**226.6**

Source: U.S. Energy Information Administration, *Commercial Nuclear Power: Prospects for the United States and the Rest of the World* (U.S. EIA, Washington, D.C., 1985).

Box 7.1 The Environmental Impacts of Fossil Fuels

All fossil fuels affect the environment to some extent, but the impacts of coal production and use are potentially the most serious. Coal extraction operations tend to have greater aesthetic effects on the landscape, particularly surface (opencast) mining, whose share of total production has grown in recent years (1).

Coal combustion emits large quantities of sulfur dioxide, nitrogen oxides, soot, ash, and dust as well as heavy metals (the amounts depend on the quality of coal burned). If not controlled, these emissions translate directly into environmental damage: the acidification of lakes, damage to buildings and metal surfaces, reduced crop yields and forest declines. (See Part III, Chapter 12, "Multiple Pollutants and Forest Decline.") These impacts represent financial as well as environmental costs. For example, it has been estimated that the financial losses arising from forest decline in West Germany amount to more than $1 billion per year (2).

It is possible to eliminate most sulfur dioxide emissions from coal-fired power stations by installing flue gas desulfurization systems. However, several countries (e.g., the United Kingdom, United States, Czechoslovakia, and Poland) have not retrofitted these systems into existing plants because they feel that the benefits would not justify the costs. These countries also export much of their emissions abroad. New, less-polluting technologies, such as fluidized bed combustion, may also help alleviate acid deposition problems.

A third and relatively intractable environmental problem associated with coal combustion (and to a lesser extent, oil and gas) is the release of carbon dioxide and its buildup in the atmosphere. (See Chapter 10, "Atmosphere and Climate.") The increases in coal consumption traditionally embodied in long-term energy projections (see "Energy Projections," below) are big enough to lead to major climate modifications. At present the only known way of avoiding a warmer earth and rising sea levels is not to burn the coal in the first place. The climate factor, therefore, could be the ultimate constraint on coal use.

Another important class of pollutants arising from fossil fuel combustion is nitrogen oxides (NO_x). In most OECD countries, about half the man-made NO_x emissions come from the transport sector (almost entirely from oil combustion) and the other half from industry and electricity generation (from oil, gas, and coal combustion) (3).

NO_x emissions are thought to be a key contributor to acid deposition and its associated damage, particularly the forest declines noted in Europe and North America. (See Chapter 12, "Multiple Pollutants and Forest Decline.")

References and Notes

1. M. Chadwick and N. Lindman, *Environmental Implications of Expanded Coal Utilization* (Pergamon Press, Oxford, 1982), p. 21.
2. Federal Ministry for Research and Technology, Bonn, West Germany, 1985.
3. Organization for Economic Co-operation and Development (OECD), *The State of the Environment 1985* (OECD, Paris, 1985), p. 21.

In the foreseeable future, the rate at which new capacity is installed is expected to slow down in most countries, owing to a combination of developments in recent years, including increased capital costs, lower load forecasts, and environmental opposition. The main environmental concerns have been reactor safety issues, particularly following the Three Mile Island accident, the disposal of radioactive wastes (see Chapter 9, "Oceans and Coasts," for a discussion of constraints on ocean disposal), and the potential overlap between the civil and military applications of nuclear fission. (See "Energy Projections," below.).

Prospects for nuclear power are particularly bleak in the United States, where capital costs per kilowatt of installed capacity have increased by a factor of four in real terms for plants being completed around now (1983–87) compared with a typical plant completed in 1971 (51). In addition, construction times have doubled, and plant performance has remained generally mediocre. Consequently, nuclear power has become a far less attractive option in economic terms. No orders for new nuclear reactors have been placed since 1978, and the 13 orders that were placed between 1975 and 1978 were cancelled or deferred indefinitely (52). Few, if any, new orders are likely in the United States during the rest of this decade.

Hydropower

World hydro-electricity consumption increased from 331.5 Mtoe in 1973 to 485.4 Mtoe in 1984, its share of total commercial energy production rising from 5.6 percent to 6.7 percent (53). North America and Western Europe consume more than 50 percent of this electricity, but their share of total consumption has been declining slightly (54). In the developing countries, on the other hand, consumption of hydro-electricity doubled from 57 Mtoe to 126.7 Mtoe between 1973 and 1984, increasing their share of world consumption from 17.2 percent to 26.1 percent during the same period (55).

In 1980, hydropower accounted for 40.8 percent of electricity production in developing countries, and this figure is expected to grow to 42.6 percent by 1995. (See Table 7.6 for a summary of hydropower development status by region.) The rate at which new projects are introduced will be constrained by cost factors, the lack of power markets near potential hydropower sources (56), and the need to take account of their potential for harmful environmental and social side effects (57).

One important side effect is the displacement of indigenous people from their traditional lands, often to poorer ones: 80,000 were displaced by the Aswan High Dam in Egypt, and 75,000 by the Lake Volta scheme in Ghana (58). Other effects include the spread of waterborne diseases such as schistosomiasis, the disruption of aquatic ecosystems, and major reductions in the flow of nutrient-rich silt to agricultural lands downstream which depend upon the silt for their fertility. Conversely, silt sometimes accumulates in the artificially created reservoirs instead, thereby sharply curtailing the dam's ability to generate electricity, as has happened, for example, to the Sanman Gorge Dam in China and Egypt's Aswan Dam (59).

BIOMASS FUELS

In the industrialized countries, wood and other biomass fuels had almost ceased to be used as energy sources prior to the 1973 oil shock, but since then they have begun to make a comeback in some countries. In the United States, Norway, and Sweden, wood use for residential heating has nearly doubled from the low values of the mid-1970s, presently accounting for more than 10 percent of the market (60). Both Canada and the United States derive 3–4 percent of their primary energy from wood, most of which is used in their forest products industries (61).

It is in the Third World, however, that biomass fuels assume greatest importance (62). As noted earlier, the official statistics on energy consumption in these countries often do not include the contribution made by biomass fuels. They do not because the data on the use of these fuels are limited, are often of poor quality, and are not usually collected on a standardized basis over a period of several years. Data collection is made particularly difficult by the fact that a large proportion of the fuels consumed are not commercial and therefore do not have any recorded transactions. Nevertheless, surveys of various kinds have demonstrated that biomass fuels, particularly fuelwood, are usually a key source of energy in developing countries. The contribution of biomass in various low- and middle-income countries is shown in Table 7.7.

Table 7.6 Hydropower Development Status by Region, 1982

Annual Technical Potential	West Africa	East Africa	South Asia	East Asia	Europe Middle East North Africa	Latin America Caribbean	100-Country Total
Potential Production (terawatt-hours)							
Installed	14	45	60	78	76	221	494
Under Construction	9	37	47	72	48	165	378
Under Investigation	48	85	90	790	47	563	1 623
Remaining	301	826	526	1 752	186	1 716	5 307
Total	372	993	723	2 692	357	2 665	7 802
Capacity (gigawatts)							
Installed capacity	3	9	14	26	19	51	122
Under construction	2	8	12	17	16	38	93
Under investigation	10	17	21	155	15	126	344
Remaining	70	182	124	356	50	335	1 117
Total	85	216	171	554	100	550	1 676

Source: The World Bank, 1984. Reference 46

Table 7.7 Percentage of Biomass in Total Energy Consumption of Selected Countries

Low Income Countries	Year	Percent	Middle Income Countries	Year	Percent
Burkina Faso[1]	1980	94	Costa Rica[4]	1978	42
Malawi[2]	1980	94	Philippines[3]	1981	38
Mali[1]	1980	93	Peru[4]	1978	35
Mozambique[2]	1980	89	Brazil[3]	1981	34
Sri Lanka[3]	1981	75	Colombia[4]	1978	24
Kenya[3]	1981	68	Chile[3]	1980	18
India[3]	1979	42	Portugal[3]	1981	7

Sources:
1. Y. Lambert, *Energy Needs in West African Countries: Possible Contribution of Renewable Energy* (Energy Research Group, Ottawa, 1984).
2. J. Simoes, Ed., *SADDC: Energy and Development to the Year 2000* (Beijer Institute/Scandinavian Institute of African Studies, Sweden, 1984).
3. Leach *et al.*, 1985, Reference 78.
4. G. Sanchez-Sierra and L.A. Umana-Quesada, "Quantitative Analysis of the Role of Biomass Within Energy Consumption in Latin America", *Biomass*, 3, pp. 21-41, 1984.

In 1983, 1.63 billion cubic meters of wood were consumed, equivalent to about 6 percent of the world's commercial energy consumption (63). Estimates of the contribution of woodfuels to the total energy budget of developing countries vary from the neighborhood of 10 percent in a few higher income Latin American countries to more than 90 percent in poorer African countries (64, 65). (See Table 7.7.) Among the rural poor, fuelwood and other forms of biomass are usually the dominant or only fuels. Altogether some 2.5 billion people depend on them to meet their daily domestic energy requirements (66). A study by the FAO, covering 95 developing countries, found that fuelwood played a significant role in all of them (67). As many as 21 of these countries depend on fuelwood for more than 75 percent of their energy supplies (68).

In developing countries most fuelwood is used for domestic purposes, particularly in rural areas. The amount of fuel used by rural households varies considerably both among and within countries. Where local supplies are plentiful, consumption tends to be higher. For example, annual consumption figures of 1,100–2,865 kilograms (kg) per person have been reported in Nicaragua (69), and 1,636–2,600 kg of wood per person are used in some parts of Tanzania (70).

Where wood is scarce, however, the quantities consumed decrease considerably. People economize on the amount of wood they use by lighting smaller fires, quenching and re-using embers which would otherwise have been allowed to burn away, and positioning or sheltering fires more carefully. Surveys in Mali and Niger measured consumption ranging from 440 to 660 kg per person per year (71). Similar consumption levels have been found in areas of wood scarcity in India (72, 73), and even lower consumption levels exist in some areas.

It is often difficult to define how much of this household energy is being used for which purposes. The cooking fire may also serve as the only source of space heating, water heating, and—in many cases—lighting. It can also be the main social focus of family life, an insect repellent, odor suppressor, and defense against wild animals. The few reliable breakdowns of rural household energy consumption available show that cooking (including water heating) is usually the most important end-use, followed by space heating and lighting. Fuelwood sometimes meets all these requirements, but kerosene (or torches and candles) are often used for lighting.

Fuelwood (and charcoal) are also used for cooking and other domestic purposes in urban areas. In addition, however, certain industries—including baking, brewing, tobacco-curing, pottery, and brick and lime-making—consume significant amounts of woodfuels in some countries. In Sri Lanka, woodfuels supply about 57 percent of industrial energy demand, in Kenya 64 percent, and in Tanzania as much as 88 percent (74).

In many regions of the world, wood has become so scarce that people turn to other sources of biomass instead, such as dung and crop residues. The greatest use of biomass residues is found in the relatively treeless plains of Northern India, Bangladesh, and China, where crop residues and dung provide as much as 90 percent of household energy in many villages and a considerable proportion in urban areas, too (75).

FOCUS ON: FUELWOOD SCARCITY

In 1983, the FAO published a study of fuelwood supplies in the Third World which showed that more than 100 million people were consuming amounts "below minimum requirements" for cooking and heating, etc. (76). In addition, nearly 1.3 billion people were in a deficit situation—and could meet their needs only by depleting wood reserves. (See Table 7.8.) More than 64 percent of these people lived in Asia. Shortages were most acute in the arid regions of Africa, in the mountainous areas of Asia, particularly the Himalayas, and on the Andean plateau in Latin America.

The future prospects are even more disturbing. The study's projections for the year 2000 suggest that, without immediate action to improve the situation, 3 billion people will either be unable to obtain their minimum energy needs or will be forced to consume wood faster than it is being grown (77). The FAO study is open to a number of criticisms, but the general thrust of its findings is widely accepted.

Fuelwood Scarcity in Rural Areas

The pattern of fuelwood collection varies enormously from one region to another. Broadly speaking, however, a distinction can be drawn between situations where

Table 7.8 Populations Experiencing a Fuelwood Deficit, 1980 and 2000[a]

(millions)

Region	1980				2000	
	Acute scarcity		Deficit		Acute Scarcity or Deficit	
	Total Population	Rural Population	Total Population	Rural Population	Total Population	Rural Population
Africa	55	49	146	131	535	464
Near East and North Africa			104	69	268	158
Asia and Pacific	31	29	832	710	1,671	1,434
Latin America	26	18	201	143	512	342
Total	112	96	1,283	1,052	2,986	2,398

Note: a. Total population and rural population (total population less that of towns with more than 100,000 inhabitants) in zones whose fuelwood situation has been classified.
Source: Adapted from Food and Agriculture Organization, 1983, Reference 67.

people live near forests and collect wood from them and those in which the wood comes from free-standing trees or bushes on relatively open land.

Village communities near forests can generally harvest fuelwood on a sustainable basis. Problems arise only when other factors intervene to deplete the forest resource. The major cause of deforestation is the clearance of forests to create new agricultural land. The reason may simply be a growing population, but changes in population distribution can also be important.

Other major causes of deforestation are logging and large-scale construction projects, such as dams or roads, developments which tend to bring further pressures in their wake as an area becomes more closely connected to population centers. These additional pressures, particularly land clearance for agriculture, may lead to the overexploitation and gradual receding of the forest, making fuelwood a scarce resource. Thus, rural fuelwood users are not so much the cause of deforestation as the victims of it (78).

Most rural families, however, live too far from forests to obtain their daily fuel needs from them. Consequently, they have to rely on the free-standing trees and bushes within walking distance from their homes for their fuel as well as for numerous other needs, such as building poles, fruit, shade, and fodder. If population densities in these areas remain low, it may be possible to satisfy the demand for fuelwood without damaging the local standing stock of trees. Where fuelwood is plentiful, usually only dead wood is collected since it is easier to cut, is lighter to carry, and burns better than green wood. Though branches may be lopped off, whole trees are rarely felled merely to provide fuel.

If the population increases, however, local supplies of dead wood may become scarce or inadequate, forcing people to spend more time searching for and collecting fuelwood. As good fuelwood becomes more difficult to obtain, people begin to economize in the way they use it. Nevertheless, population pressures may eventually be so great that people have no choice but to exploit the trees (by lopping off large branches or even chopping down whole trees) so that either they die or their productive capacity is severely degraded. Fuelwood consumption is not likely to be the only factor in this process, however, nor necessarily the most important one; livestock grazing and fodder gathering may also be major contributors to the stunting or killing of trees.

When demand exceeds the rate at which the trees are able to regenerate, people have to turn to tree roots, crop residues, dung, and other combustible biomass materials as replacements for or supplements to fuelwood.

The shift to other biofuels expands the amount of fuel available, but there are good reasons why residues are often turned to only as a last resort. Cow and buffalo dung produce a lot of smoke, which can be irritating to eyes and lungs; while most crop residues (such as cereal straw and lightweight stalks) demand more time and care in feeding and tending the fire than wood does. Dung and agricultural residues may also be serving a valuable role as fertilizers.

The Impact of Urban Use

The majority of fuelwood is purchased in towns and cities. The wood or charcoal that urban household and industrial consumers buy is often carried or trucked in from rural areas, and the money they pay for it gives a strong incentive to both organized businesses and poor peasants to cut down living trees.

As a result of urban woodfuel demands, an expanding "ring of desolation" surrounds many cities, such as Dakar (Senegal), Ouagadougou (Burkina Faso), and Niamey (Niger). In addition to collection by the urban and peri-urban poor in the vicinity of towns and cities, a large proportion of the woodfuels consumed in urban areas is supplied by organized commercial operations that often truck the fuel in from far afield. Much of the wood is converted into charcoal first since it is lighter and easier to transport. Studies in Hyderabad, Kenya, and elsewhere have shown that wood supplies often come from about 100 kilometers away and charcoal from a few hundred kilometers (79).

Large areas of trees may be removed with little concern for the environmental costs since these do not affect the urban consumer directly. Urban demands for woodfuels and timber are the primary cause of deforestation in Southern Africa (80). On a global basis, urban consumption of wood may be more responsible for depleting rural fuelwood supplies than local consumption (81).

Consequences and Responses

A decade ago, it was widely believed that fuelwood scarcity was a problem that would solve itself with time, as people gradually shifted toward the use of fossil fuels and electricity. However, the major increases in fossil fuel prices and the lack of progress in dealing with poverty in the Third World have led to a shift in attitudes.

Fuelwood scarcity has several harmful consequences. It causes increasing hardship to the rural poor, due to the large amount of time spent in collecting fuel. Thus, fuel gathering joins water collection as a source of daily drudgery, cutting into potentially productive time, especially for women. Ultimately, scarcity may also lead to health problems if people are forced to cook less or turn to less nutritious foods. The urban poor, on the other hand, may be faced with rising fuelwood prices, and even if other fuels become competitive, the poor often cannot afford the initial investment in the necessary gas or kerosene stoves.

Loss of tree cover can also have disastrous environmental consequences. Trees play a vital role in restoring soil fertility and maintaining soil structure, so their removal tends to be followed by loss of topsoil due to wind or water erosion, particularly in arid zones, mountains, and other fragile ecological areas. In certain circumstances, the switch from woodfuels to crop and animal residues can exacerbate the ecological damage arising from the loss of tree cover, leading to reductions in crop yields (82).

New initiatives aimed at alleviating the situation have focused primarily on two basic approaches — using fuelwood more efficiently and planting more trees (83).

Although simple and obvious in the abstract, these measures have proved to be surprisingly difficult to implement.

In the mid-1970s, as awareness of fuelwood problems increased, there was a great deal of interest in wood conservation through the development and dissemination of more efficient cookstoves. Laboratory findings that the traditional method of cooking over "three-stone fires" used only 3–10 percent of the useful energy led to considerable optimism that efficient cookstoves would result in major fuel savings—perhaps as much as 50 percent—and hence widespread adoption.

The experience of numerous stove programs has identified many obstacles to their extensive introduction—including technical, economic, and cultural factors (84, 85). Technical difficulties include serious discrepancies between laboratory and field performance and declining fuel efficiency due to rapid deterioration and breakage. The major economic barrier has been that stoves cost several dollars to buy (as much as $30 or more for certain types of stoves) in contrast to the open fire. Cultural barriers tend to arise from the fact that fires meet other needs, such as lighting and heating, as well as cooking, which the stoves are not designed to meet; in addition, the open fire is more adaptable than most stoves to variations in the size or number of pots. (See Box 7.2.)

In view of the limited scope for improving the efficiency with which fuelwood is used in the home, new sources of fuelwood (to replace those being depleted) or substitute fuels are essential in alleviating the problems of fuelwood scarcity. As with modern cooking stoves, the concern over fuelwood scarcity prompted programs to plant trees, but again many of them encountered unexpected problems (86).

Various factors such as legal constraints on tree cutting, no legal entitlement to the land on which the trees were to be grown, or simply low priority in the minds of the local people have hindered tree planting efforts. However, even if the barriers to tree planting are overcome and there is much greater local commitment and official support than in the past, it will be impossible in many areas to bring the supply of fuelwood into balance with the projected demand. Other energy sources, such as kerosene and bottled gas, will have to begin to replace fuelwood.

In many countries it may simply prove impossible to solve the fuelwood crisis through stove and tree-growing programs alone. Only when their incomes rise will the rural poor be able to buy efficient cook stoves, switch to alternative fuels, or find it unnecessary to cut down trees for sale to urban consumers. Problems arising from fuelwood scarcity can be fully and effectively dealt with only in the context of poverty-focused strategies for development.

ENERGY USE PATTERNS IN THE FIRST WORLD

Energy Efficiency

Since the first OPEC price rises, there have been significant improvements in the efficiency with which energy is used in all the major energy sectors—residential, service, transport, and industry—in the western industrialized countries.

In the *residential* sector, factors like higher levels of thermal insulation and weatherization (draft-stripping) of the "shells" of buildings and more efficient appliances (such as stoves and refrigerators) have reduced the amount of energy required to satisfy household needs. Thus, despite increases in room temperatures and the more widespread use in recent years of various appliances (e.g., freezers), energy use per dwelling has declined in most OECD countries, as Figure 7.5 shows.

Box 7.2 "How Much Wood Would a Wood Stove Save, if a Wood Stove Could Save Wood?"

Many lessons have been learned from the problems encountered by earlier stove programs. Originally, many stove programs hoped to disseminate improved models that families could build themselves. More recently, as the technical demands of stove efficiency and durability have become more apparent, emphasis has shifted toward models that can be built by well-trained artisans at low cost. Metal stoves have proved to be more effective than mud stoves in certain situations because they are amenable to mass manufacture and careful quality control, and they also tend to last longer. A project in West Africa introduced a new metal stove that is achieving 30–35 percent average fuel savings relative to open fire cooking or use of the traditional metal stove of the region (1).

For a number of reasons, the potential of stoves to reduce fuelwood consumption appears to be limited largely to urban areas (2). Many people living in rural areas simply cannot afford to buy a stove. Most of them have less incentive to do so than the urban population because they gather rather than buy the wood and therefore would not save money by switching to a stove. In addition, the capability for mass-producing high quality metal stoves tends to exist primarily in urban areas, whereas short-life mud stoves may be the only option in many rural areas. For these and other reasons such as the inability of stoves to provide adequate lighting in certain circumstances (an important obstacle in rural areas of Kenya, Malawi, and West Bengal, for example), many experts no longer expect improved cooking stoves to make a major impact on fuelwood consumption at the national level (3,4). Nevertheless, they can produce benefits for some groups of people, and they may also have other advantages such as reducing smoke pollution (a serious health problem in relatively confined spaces) and fire hazards.

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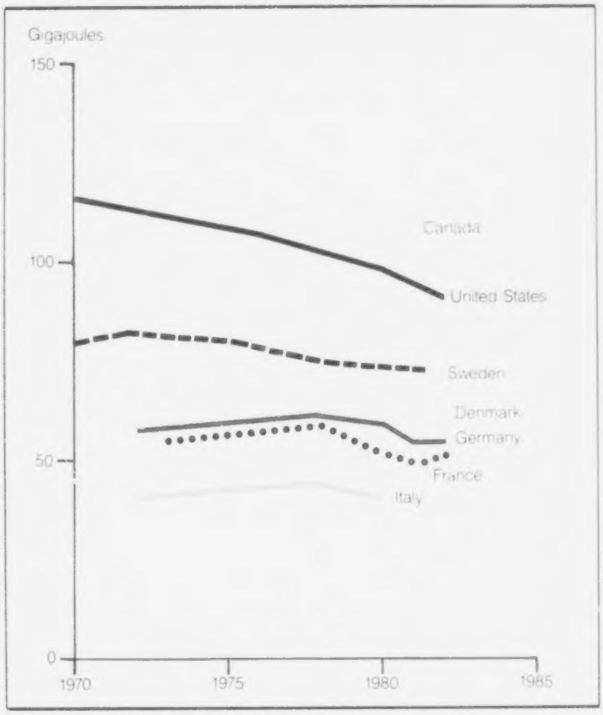
Figure 7.5 Energy Use Per Dwelling in Selected OECD Countries, 1970-82



Source: Schipper *et al.*, in press. Reference 13

The potential for further improvements in household energy use is substantial. Overall, average energy use in "all-electric" homes in the United States and Sweden (and probably several other OECD countries) could be reduced by about 80 percent if the most energy-efficient technologies commercially available were introduced to replace the older, less efficient ones (87).

In the *service* sector, which includes commercial and public sector buildings, improvements similar to those in the residential sector have taken place, and further improvements are technically and economically feasible. One survey of informed opinion (experienced architects and engineers) in the United States suggested that a 50 percent reduction in energy use per square meter, on average, was an achievable target for U.S. commercial buildings by the turn of the century (88).

In the *transport* sector, there is further scope for improving the fuel economy of automobiles and light trucks from current levels of about 12–8 liters per 100 kilometers (20–30 miles per gallon) to 4–2.3 liters per 100 km (60–100 m.p.g.), both by increasing engine and drive train efficiency and by reducing vehicle weight and aerodynamic and rolling resistances (89). There has also been a trend toward greater efficiency in air travel, and a 50 percent reduction in the fuel intensity of passenger aircraft, relative to 1977 levels in the United States, appears feasible (90).

Industrial energy efficiency trends are more difficult to assess in some ways than those in other sectors because of the greater heterogeneity and complexity of energy use in this sector. As in the other sectors, efficiency improvements may come from good housekeeping measures or new energy conversion systems, but they may also arise from new technological processes for producing a given product (e.g., steel) and from product changes. For example, new processes for producing steel could halve the amount of energy required (91); and similar process innovations are also in prospect for other industries. Two notable examples of more efficient energy conversion technologies are combined heat and power (also known as "cogeneration") systems and electric motors using variable speed drives.

Overall, the scope for cost-effective improvements in energy productivity throughout the economies of the western industrialized countries is very large. The rate at which these improvements are made is largely determined by market forces, particularly fuel prices and the rate of turnover of the capital stock (cars, household appliances, industrial machinery, etc.). The decade following the 1973–74 oil shock was one of exceptionally rapid improvements in energy productivity because of the huge increases in the price of energy. With the prospect of fuel prices declining in real terms, the incentive to introduce some of the efficiency improvements described above may weaken, and their rate of penetration is liable to slacken off. However, energy efficiency improvements can be encouraged by public policy measures, driven by environmental and resource reasons. (See "Energy Projections," below.)

Structural Trends in the Industrialized Countries

Two basic types of structural change have been taking place in the western industrialized countries that reduce their energy intensity. First, there is the growing importance of services (banking, education, health, etc.) relative to industry, a trend noted for several decades. This phenomenon is reflected in changes in employment patterns and in the fact that the output of the goods-producing sector has not been growing as fast as the GNP.

Second, there has been a decline in some of the most energy-intensive industries in Western Europe and North America, such as iron and steel. This is partly due to the recession and to competition from lower-cost producers in developing countries. But there is also evidence of a longer term shift away from most energy-intensive industries (i.e., those processing basic materials) and toward fabrication and finishing activities, which typically require tenfold less energy per unit of output (92). This shift appears to be due to a combination of factors, including more efficient use of materials in providing essentially the same services, materials substitution, and market saturation. For both traditional materials (steel, cement, and paper) and modern materials (aluminum, ethylene, ammonia, and chlorine) per capita consumption stopped growing in the United States in the 1970s and in most cases began to decline (93). Similar trends have also been observed for the same materials in France, the United Kingdom, and West Germany (94). (See Part IV, Table 8.5.)

Energy Intensity

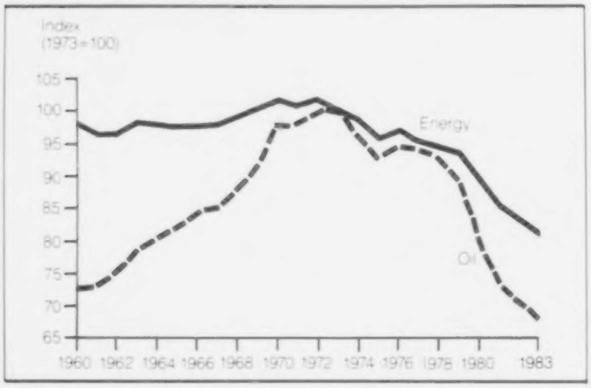
The general trend toward greater energy efficiency and the structural changes noted above have all contributed to an overall change in the relationship between total primary energy consumption and the level of economic activity, i.e., in energy intensity. (See Part IV, Table 8.2.) Saturation in the demand for various energy-intensive services (such as private transport, central heating, and refrigeration) also appears to have reduced energy intensity. This decline for the IEA countries as a whole can be seen in Figure 7.6.

ENERGY PROJECTIONS

Until the 1973–74 oil shock, and for sometime after, forecasts of energy demand were largely extrapolations of past trends, with some allowance for increases in economic activity and changes in fuel prices. This approach, sometimes known as the "top-down" approach, tended to treat energy demand in a highly aggregated way and assumed that it has a fixed relationship with other variables like fuel prices and GNP. In recent years, however, there has been growing uncertainty about the validity of energy projections formulated in this way. Because the major increases in oil prices (and other energy prices) that occurred in the 1970s were without precedent in recent decades, their longer-term effects on the relationship between energy demand and economic activity are not yet clearly understood (95). In addition, many forecasts during the late 1970s tended to assume historic rates of economic growth and of growth in particular sectors, which proved to be serious overestimates.

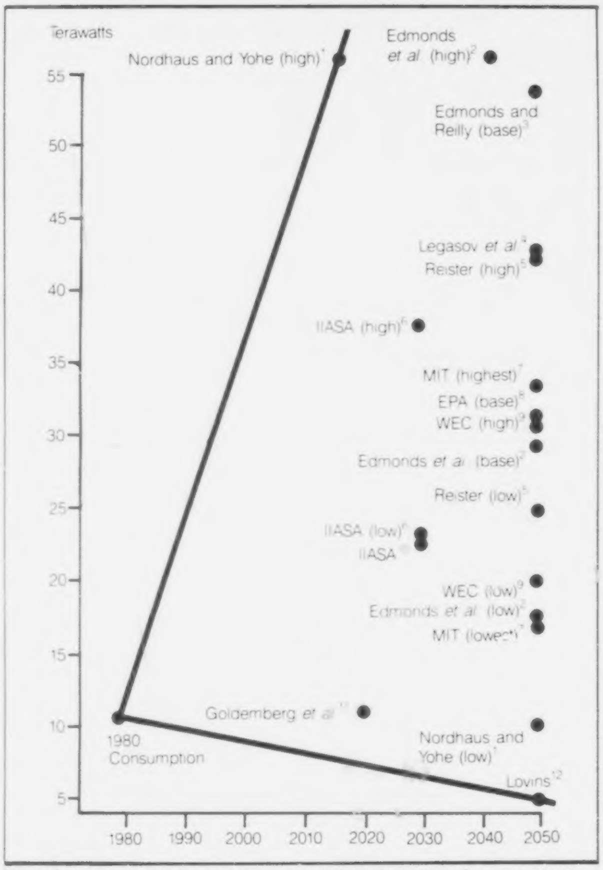
Two important examples of "top-down" projections are those produced by the International Institute of Applied Systems Analysis (IIASA) and those of the World Energy Conference (WEC) (96, 97). (See Figure 7.7.) In both cases there are two projections—high and low demand—based

Figure 7.6 **Energy and Oil Intensities for IEA Countries, 1960-83**



Source: International Energy Agency (IEA), 1984. Reference 17.

Figure 7.7 **Comparison of 19 Long-term Projections of Primary Energy Consumption, 1980-2050**



Note: Some studies of future energy demand produce more than one projection. The projection that gives the highest or higher level of demand is usually called the "highest" or "high" projection, and the one that gives the lowest or lower level of demand is called the "lowest" or "low" projection. A projection between these two extremes is often called the "base" projection. The fact that the same study may produce a range of projections is related to the fact that varying assumptions are made about the major determinants of energy demand, such as the rate of economic growth and the rate at which energy efficiency improvements occur. (See Table 79 and the accompanying text for examples of such variations in assumptions.)

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on different assumptions about economic growth, fuel prices, etc. The assumptions about two key influences on energy demand, population growth and per capita GDP growth, are given in Table 7.9, as are the energy demand and supply projections. The IIASA modeling exercise produced demand projections for the year 2030 which are 3.5 and 2 times the 1980 consumption level for the high and low scenarios, respectively. The WEC projections are quite similar, giving demand figures for the year 2020 which are 2.5 and 2 times the 1980 level for the high and low growth cases, respectively.

These large anticipated increases in energy consumption are a common feature of energy projections based on the econometric "top-down" approach. There are two reasons for this. First, the usually highly aggregated nature of the projections does not lend itself to identifying the potential for reducing demand through the more efficient use of energy. Second, the scenarios tend to be "business as usual" in that they implicitly assume the continuation of current financial (taxes, subsidies, etc.) and institutional (regulations, building codes, etc.) factors which shape the pattern of energy usage, usually in a way that discourages energy efficiency.

The levels of demand projected in the IIASA and WEC studies would require huge expansions of both fossil fuel and nuclear energy supplies, and therefore they imply a general exacerbation of the environmental impacts of energy use. For example, even under IIASA's "low demand" projection, fossil fuel use would result in a doubling of the atmospheric carbon dioxide concentration in the second half of the next century, with consequent climatic changes. (See Chapter 10, "Atmosphere and Climate.") Estimated use of nuclear technology in IIASA's high and low demand projections would mean that by 2030 some 2.6–4.0 million kg of plutonium would be recovered from spent reactor fuel and circulated each year in global commerce (98). Since plutonium is a nuclear explosive and only 5–10 kg are required to make a nuclear weapon, this traffic in plutonium for nuclear energy purposes would provide a major stimulus for the spread of nuclear weapons.

The changing relationships between energy demand, on the one hand, and fuel prices and economic activity on the other, have given rise to corresponding uncertainties about the utility of projections based solely on the "top-down" approach; consequently there has been more use in recent years of models based on the actual end-uses to which energy is put. This "bottom-up" approach uses a highly disaggregated model of energy use that makes explicit assumptions about how energy consumption changes over time for a large number of specific end-uses such as refrigeration and cooking.

One recent study of this kind formulated a demand scenario significantly lower than those produced by IIASA and WEC (99). As Table 7.9 shows, the Goldemberg *et al.* projection for the year 2020 is 11.2 TW (Terawatts), whereas the others range from 19.2 to 35.2 TW.

A wide range of energy supply mixes, such as the one in Table 7.9, are compatible with lower demand projections. The key characteristics of this supply mix are that fossil fuel consumption is no higher than it was in 1980; coal use is reduced, partly to reduce the carbon dioxide problem; and the use of plutonium as a nuclear fuel is unnecessary, making it possible to minimize the threat of nuclear weapons proliferation.

This second approach to the formulation of energy projections reflects a crucial recognition that has emerged in recent years—namely, that the future use of energy is not a preordained consequence of economic growth, but can be influenced to a significant degree by society's preferred choices.

RECENT DEVELOPMENTS

THE UNDP/WORLD BANK ENERGY SECTOR ASSESSMENT PROGRAM

By the end of 1986, a major international energy program focused on the Third World will have been

Table 7.9 Comparison of Three Global Energy Studies

		IIASA		WEC		Goldemberg *et al.*
	1980	High	Low	High	Low	
Projection Year		2030		2020		2020
Population (billions)	4.43	7.98		7.72		6.95
Per Capita GDP Growth Rate to Year of Projection (percent per year)		2.10	1.10	2.00	1.10	a
Primary Energy (TW)[b]						
World	10.30	35.20	22.00	24.70	19.20	11.20
Industrialized Countries	7.00	20.10	13.50	14.80	12.50	3.90
Developing Countries	3.30	15.10	8.40	9.90	6.70	7.30
kW/cap, World	2.33	4.41	2.76	3.20	2.49	1.61
Industrialized Countries	6.30	12.90	8.64	9.67	8.15	3.15
Developing Countries	1.00	2.35	1.32	1.59	1.08	1.28
Energy Supply (TW)						
Oil	4.18	6.83	5.02	5.31	4.26	3.23
Gas	1.74	5.97	3.47	4.59	3.42	3.23
Coal	2.44	12.00	6.45	7.74	6.06	1.95
Hydropower	0.19	0.52	0.52	0.70	0.52	0.46
Nuclear Power	0.22	8.09	5.17	3.21	2.31	0.75
Other	1.49	1.81	1.33	2.65	2.65	1.58

Notes:

a. No global GDP growth rate was explicitly assumed. However, the energy demand projection is consistent with per capita GDP increasing 1.5 to 2-fold in industrialized countries and up to 10-fold in developing countries. These assumptions are consistent with a global per capita GDP growth rate of up to about 3 percent per year.

b. Here TW is an abbreviation for TW-years/year and kW an abbreviation for kW-years/year. Nuclear power is counted as the fossil fuel equivalent for producing the same amount of electricity. Hydroelectricity and other solar electric sources are counted as the electricity produced. Includes non-commercial energy, feedstocks, and bunkers.

Source: Adapted from Table 1 in J. Goldemberg *et al.*, 1985, Reference 87.

completed—the Energy Sector Assessment Program (ESAP). ESAP was launched in November 1980 as a joint effort of the United Nations Development Program (UNDP) and the World Bank. ESAP's general objective has been to help developing countries establish a realistic strategy for energy sector development and management and to assist these countries, donor agencies, and private investors in implementing the priority activities included in such strategies.

ESAP assessments are carried out on a country-by-country basis at the request of the relevant government. Originally, it was envisioned that 60 country studies would be done, but a positive response from developing country governments resulted in this figure being increased to 70. The majority of these studies have been carried out, and the remaining ones should be completed during 1986.

Several common issues have been identified by the ESAP studies. It was found, for example, that the rehabilitation and maintenance of existing energy-producing and energy-using facilities tended to produce very high economic returns and therefore warranted investment priority. This was particularly noticeable in the power subsector for countries like Sudan, Liberia, and Zimbabwe, where a low-cost investment in, for example, reducing the loss of electricity from the power system's transmission and distribution network, can produce major savings.

Securing an adequate long-run supply of household fuels at affordable prices was another major issue. Tree planting alone was found to be inadequate to meet current, let alone future, requirements. Efforts are also needed to improve the efficiency with which woodfuels are used and to introduce or expand the availability of commercial fuels. Another common feature of the assessment reports is the finding that in countries like Bangladesh, Indonesia, Bolivia, and Nigeria, commercial energy prices tend to be set below the cost of supply and kept down by government subsidies.

The earlier ESAP reports tended to give insufficient attention to some key areas, such as household and rural energy use and energy efficiency improvements. In more recent reports, however, efforts have been made to rectify this deficiency. Another weakness identified in the early stages of the program was the need for additional assistance to accelerate follow-up activities. This was particularly the case for pre-investment work in areas such as energy efficiency improvements and power sector rehabilitation.

The need for further assistance with follow-up activities led to the setting up of a companion program, the Energy Sector Management Assistance Program (ESMAP), in April 1983. ESMAP reviews progress in implementing the recommendations of the ESAP assessments and recommends priority technical assistance measures.

ESMAP also carries out project formulation and justification work which takes priority investment projects to the pre-feasibility or feasibility stages. As of April 1985, ESMAP's work in this area covered 50 projects, 20 of which were concerned with renewables/biomass, 15 with the electric power subsector, 13 with energy efficiency, and two with fuel substitution. Finally, ESMAP assists countries in strengthening their energy sector institutions.

ESAP assessments have been criticized by some countries on the grounds that the speed with which they were carried out resulted in important areas or issues being inadequately addressed—as happened with household energy use, for example, in the earlier studies.

It has also been argued that the assessments should be more highly disaggregated in their analyses so that end-uses, energy conversion technologies—and, in the case of industry, process technologies—can be thoroughly assessed. Some of the assessments have also been far too aggregated in their treatment of biomass fuels, not taking proper account of regional variations. Despite these criticisms, ESMAP and ESAP are widely felt to have been successful in helping developing countries formulate strategies and projects to deal with their enormous energy problems.

HARD TIMES FOR OPEC

September 1985 marked the 25th anniversary of the most powerful and effective resource cartel that has ever existed—the Organization of Petroleum Exporting Countries, or OPEC, as it is commonly known.

OPEC rose to public and political prominence in 1973, when its quadrupling of oil prices sent shock waves through the world's market economies and precipitated a global recession. Countries had become increasingly dependent on oil during the 1950s and 1960s because its low costs rendered other fuels uncompetitive. By 1973, the OPEC countries accounted for 53.5 percent of world oil production and 64.7 percent of the non-communist world (NCW) oil production (100).

Twelve years later, the situation has changed drastically; OPEC's ability to determine oil prices, and through that to influence the state of the world economy, has diminished sharply. By 1984, its share of world oil production had fallen to 32 percent, its share of NCW oil production to 43 percent, and the downward trend continued during 1985. Between the oil price rises of 1979 and 1985, OPEC production fell by half—from 31.5 million barrels a day to about 16 million barrels a day.

How did these changes come about? The historic trend of rapidly increasing oil consumption came to an end, with global consumption in 1984 only slightly higher than it had been in 1973 and NCW consumption somewhat lower. Consequently, increases in non-OPEC oil production had a bigger impact on the supply picture than would otherwise have been the case. Higher prices made it possible to develop new sources, especially those off-shore. Important examples of new non-OPEC production are North Sea oil, whose share of NCW production rose from zero in 1973 to 6 percent in 1984, and oil from Mexico, whose share of NCW production increased from 1.1 percent in 1973 to 7.2 percent in 1984 (101).

OPEC's response to the fall in demand for its oil was to impose production quotas on its members so that the price it had set could be maintained. Saudi Arabia has been the single biggest OPEC producer and has acted as the "swing producer," adjusting its output so that other OPEC members could enjoy more stability. During the 1979–81 period, Saudi Arabia increased its production but since then has steadily reduced its output to well below its allotted quota. This decrease, combined with the fact that other OPEC producers have not been keeping to their production quotas, has been creating stresses and strains within the cartel.

Saudi Arabian production peaked in 1980–81 at almost 10 million barrels daily, but then dropped rapidly, reaching 4,690,000 barrels daily in 1984. By August 1985, Saudi Arabian production had slumped to around 2.4 million barrels per day. This fall in output was, of course, paralleled by a fall in revenues: the Saudis' oil revenues in 1984 were $43.7 billion, $70 billion less than three years earlier, and during 1983 and 1984 their foreign exchange reserves fell by 40 percent. Saudi Arabia was running a current account deficit of $20 billion a year—the world's biggest after that of the United States—which threatened to erode its $130 billion of foreign assets.

The situation could not continue, and in the fall of 1985, Saudi Arabia signed contracts with Exxon, Mobil, and Texaco that pegged the price of oil not to OPEC's official price ($28 a barrel of Arabian light crude) but to the value in the marketplace of the refined oil products—gasoline, heating fuel, and diesel—that are derived from crude. In effect, this pricing meant that Saudi Arabia would be selling the oil at about $2.50 less than the official OPEC price. In addition, Saudi Arabia began to expand its output again.

The effect of the Saudis' actions was not felt immediately because the demand for oil increases during the winter and because world inventories of oil were unusually low. It is widely expected, however, that they will start to have a major impact on oil prices later in 1986, leading to further price erosion. A further slackening of demand in Western Europe and an expansion of output by Iraq and Iran are other factors that could cause a drop in prices.

While the level to which oil prices will drop is uncertain, it does seem that the OPEC countries have lost the two pillars of their power—pricing and production controls. OPEC may well return to a position of strength in the 1990s if oil demand picks up again. But for the rest of this decade, it looks as though OPEC will have no more power than any other resource cartel.

References and Notes

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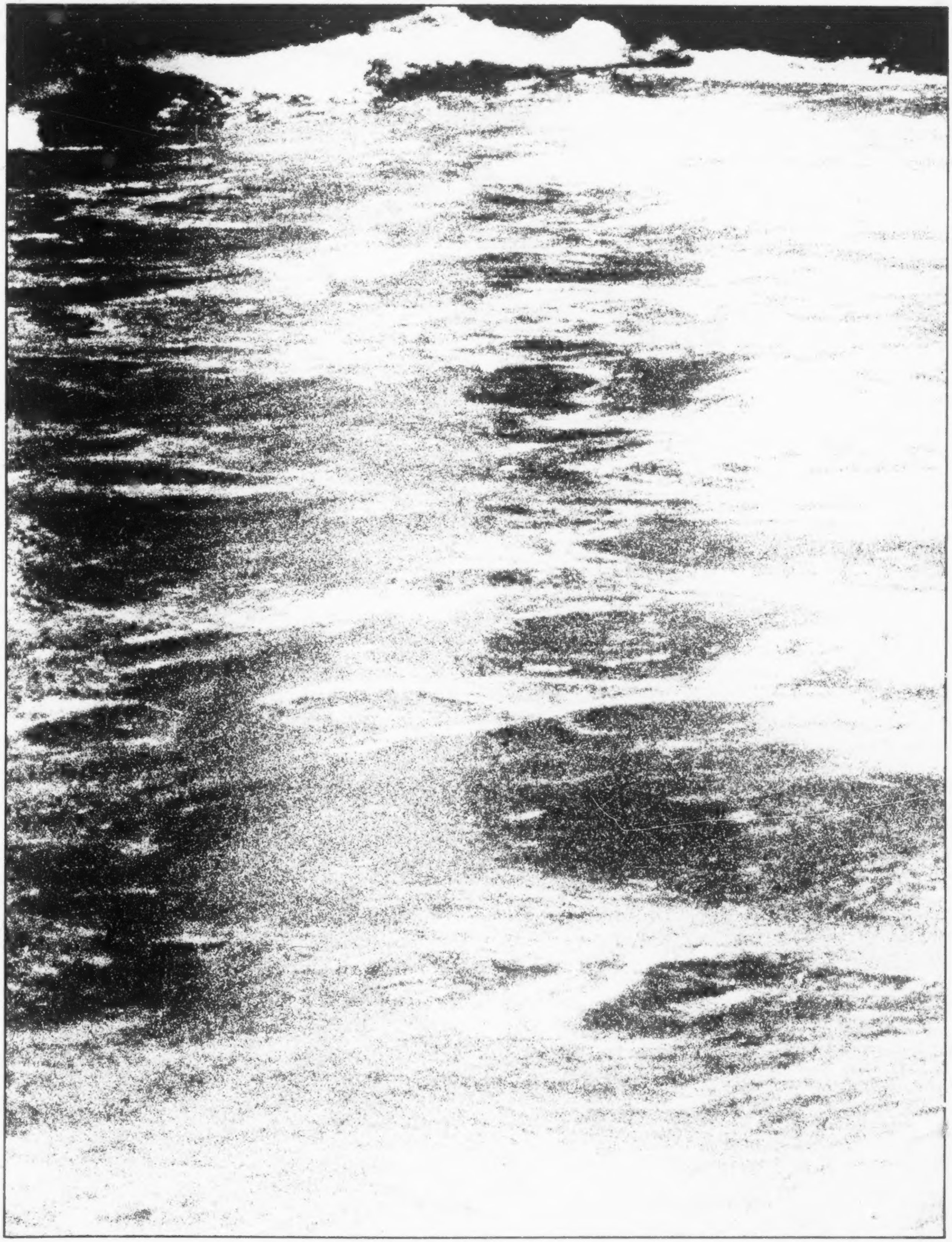

8. Freshwater

Above all else, solar energy and water maintain the life-support systems on earth. Out of a total water volume of approximately 1.4 billion cubic kilometers (km^3), more than 97 percent is ocean water, unsuitable for human use. Of the 3 percent of the earth's water that is fresh, an estimated 77.2 percent of this is in "cold storage," frozen in ice caps and glaciers. Most of the remaining supplies of freshwater—22.4 percent—is groundwater and soil moisture. This leaves only a very small amount of surface freshwater—0.35 percent contained in lakes and swamps and less than 0.01 percent in rivers and streams (1). Table 8.1 shows these amounts as "water compartments." Obviously, freshwater is a limited resource: there is only so much of it circulating throughout the planet's ecosystems.

Ancient Romans had access to roughly the same amount of water as the modern Romans do. The critical difference is population: in 100 AD Rome had a population of 1 million, while today it is closer to 4 million (2). Clearly, burgeoning populations not only need increasing supplies of freshwater for an expanding array of uses, but societies must learn to use existing resources more efficiently.

CONDITIONS AND TRENDS

FRESHWATER AS A FINITE RESOURCE

In general, water availability is tied to the global hydrological cycle (3). (See Figure 8.1.) Every year approximately 453,000 cubic kilometers (km^3) of water are evaporated from the surface of the world's oceans (1 cubic kilometer equals 1 billion cubic meters or 1 trillion liters). Of this tremendous amount, roughly 90 percent returns to the oceans as precipitation, while the remaining 10 percent (about 41,000 km^3) is transported by the prevailing winds over the continents. Here it combines with slightly more than 72,000 km^3 of evaporated water from the land masses to provide a gross continental precipitation of about 113,000 km^3. It is this "flow" of water—enough to cover the land surface of the earth to a depth of 83 centimeters—that sustains natural and human ecosystems on an annual basis. A larger portion of it goes to recharge soil moisture and groundwater flows. The rest, both surface and shallow sub-surface water—some 41,000 km^3—eventually gathers in rivers and is returned to the sea to complete the cycle (4). An equilibrium is maintained between the inflow as air moisture to the continents, and the outflow from the rivers and groundwater aquifers to the sea.

Table 8.2 shows the world's average annual water balances by major regions (5). It is the amount of stable runoff in any given area that determines how much water is actually available for human use on a year-round basis. Mark L'vovich, of the Institute of Geography, USSR Academy of Sciences, defines stable runoff as the "base flow" from groundwater into rivers plus stable "surface runoff" added by water storage in lakes and reservoirs.

Table 8.1 The Earth's Water Compartments: Estimated Volume of Water in Storage and Average Residence Time in the Earth's Environments

Environmental Parameter	Volume (km^3)	Average Residence Time
Atmospheric Water	113,000	8 to 10 days
Oceans and Open Seas	1,370,000,000	4,000+ years
Freshwater Lakes and Reservoirs	125,000	From days to years
Saline Lakes and Inland Seas	104,000	—
River Channels	1,700	2 weeks
Swamps and Marshes	3,600	Years
Biological Water (used by plants)	65,000	1 week
Moisture in Soil and Unsaturated Zone (zone of aeration)	65,000	2 weeks to 1 year
Groundwater	4,000,000 to 60,000,000	From days to tens of thousands of years
Frozen Water (glaciers and ice caps)	30,000,000	Ten to thousands of years

Sources:
1. R.L. Nace, Ed., *Scientific Framework of World Water Balance*, Technical Papers in Hydrology No. 7, Table 2 (UNESCO, Paris, 1971)
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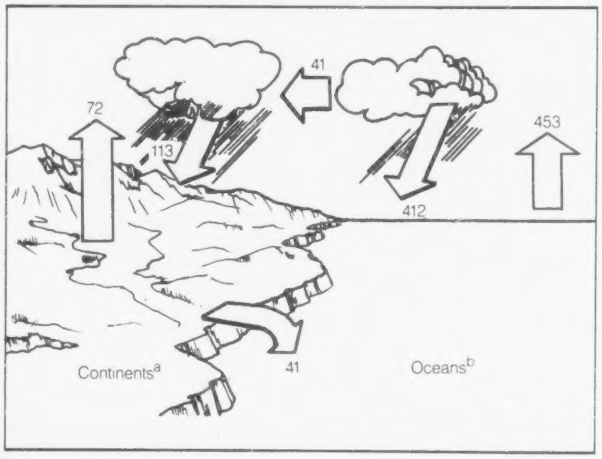
The hydrological cycle does not spread water around in an equitable manner; it is unevenly distributed around the globe even within relatively small countries. In a general sense, the world is divided into water surplus and water deficit regions. Figure 8.2 sketches in these regions, which are categorized according to water availability as seen from a vegetation perspective. Water is in surplus when precipitation is large enough to satisfy the demands of the vegetation cover. When precipitation is lower than this potential demand, there is a water deficit. By this yardstick, most of Africa (except for a small section of tropical West Africa), much of the Middle East, the western United States and northwestern Mexico, parts of Chile and Argentina, and all of Australia (except for a thin slice of eastern coastline) are areas of severe water deficits, where evapotranspiration exceeds annual precipitation.

Figure 8.1 Global Circulation of Water (thousands of cubic kilometers per year)



Notes:
a. 29 percent of earth's surface.
b. 71 percent of earth's surface.
Source: M. Falkenmark, "Do We Need Hydrological Research?", in Swedish, *Forskning och Framsteg*, No. 5, 1974.

The natural unit of the hydrological cycle is the river basin, or any drainage area forming a segment of that basin. A water divide separates basins or sub-basins from each other. All precipitation falling within the water divide that does not evaporate or leave by a deep aquifer is drained by a stream or river. Where the hydrographic pattern produces small river basins, there may be many of them within a particular country, such as Sweden, whereas large river basins like the Rhine, whose watershed extends over 220,000 square kilometers, may encompass a half dozen countries (the Rhine drains parts of Austria, Switzerland, France, West Germany, Liechtenstein, and Holland). The amount of water available to any particular country is supplied in two ways: through the inflow of exogenous water from upstream countries—which is essentially controlled by those countries—and from endogenous water provided by the precipitation falling over a country's territory (6).

The precipitation pattern, particularly its seasonality, is reflected in river flow. During the year, the flow fluctuates between dry season flow (low flow) and wet season flow (flood flow). The dry season flow forms the dependable part of the water supply, whereas the rapidly passing flood water is available only during part of the year. If this water is stored in reservoirs, it increases the dependable flow of water (stable runoff) available for societal uses.

The relative amount of water available for use in any given area is limited not only by the water cycle, in particular the stable runoff, but also by the size of the population: the larger the population, the more people there are competing for water resources. In some cases

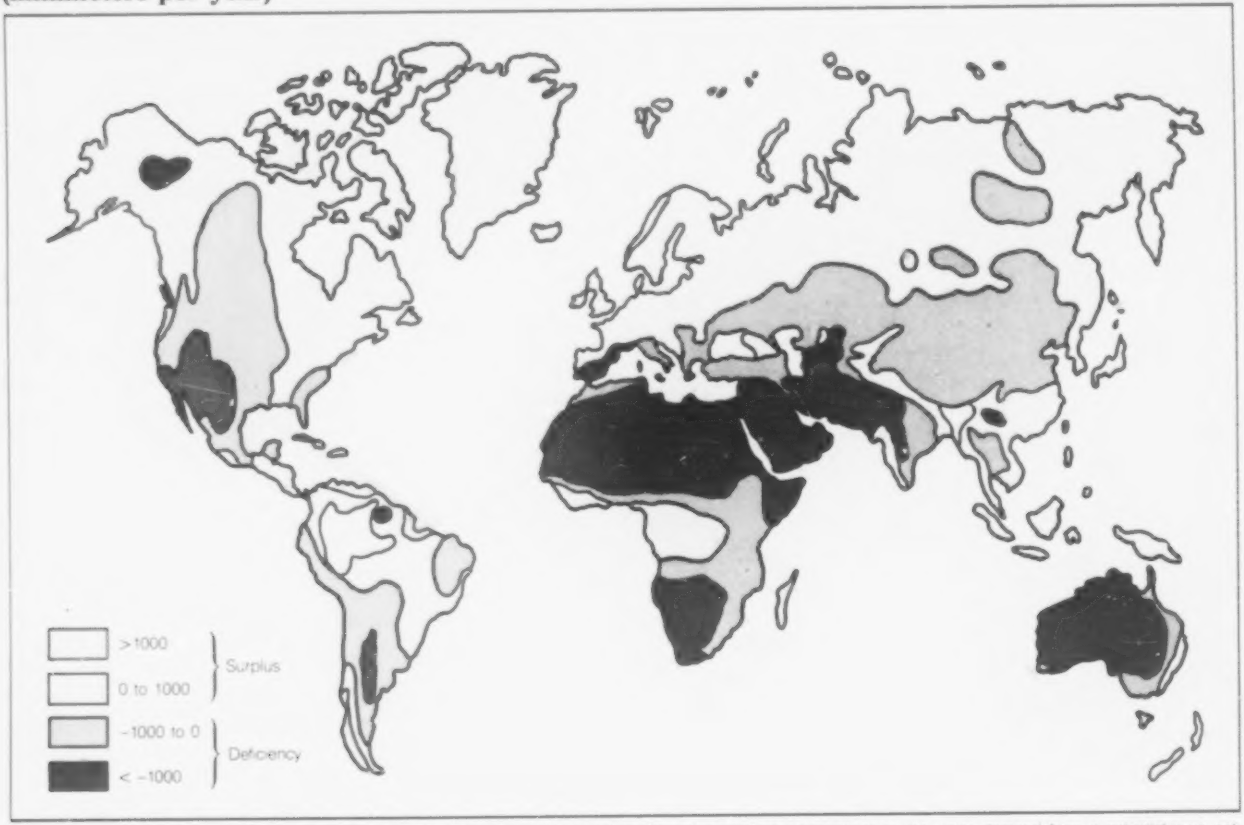
Table 8.2 Average Annual Water Balances of the World: A Comparison of Three Estimates

Region	Baumgartner[a] 1975			USSR Monograph[b] 1974			L'vovich[c] 1974		
	P[d]	E[d]	R[d]	P	E	R	P	E	R
	Volume of Water (thousands of cubic kilometers)								
Europe	6.6	3.8	2.8	8.3	5.3	3.0	7.2	4.1	3.1
Asia	30.7	18.5	12.2	32.3	18.1	14.1	32.7	19.5	13.2
Africa	20.7	17.3	3.4	22.3	17.7	4.6	20.8	16.6	4.2
Australia	7.1	4.7	2.4	7.1	4.6	2.5	6.4	4.4	2.0
North America	15.6	9.7	5.9	18.3	10.1	8.2	13.9	7.9	6.0
South America	28.0	16.9	11.1	28.4	16.2	12.2	29.4	19.0	10.4
Antarctica	2.4	0.4	2.0	2.3	0	2.3	X	X	X
Land Areas[e]	111	71	40	119	72	47	113	72	41
Oceans	385	425	-40	458	505	-47	412	453	-41
World	**496**	**496**	**0**	**577**	**577**	**0**	**525**	**525**	**0**
	Depth of Water (continent-wide average) (millimeters)								
Europe	657	375	282	790	507	283	734	415	319
Asia	696	420	276	740	416	324	726	433	293
Africa	696	582	114	740	587	153	686	547	139
Australia	803	534	269	791	511	280	736	510	226
North America	645	403	242	756	418	338	670	383	287
South America	1,564	946	618	1,595	910	685	1,648	1,065	583
Antarctica	169	28	141	165	0	165	X	X	X
World	**973**	**973**	**0**	**1,130**	**1,130**	**0**	**1,030**	**1,030**	**0**

X = Not available

Notes:
a. A. Baumgartner and E. Reichel, *The World Water Balance* (Elsevier, Amsterdam, 1975).
b. USSR, National Committee for IHD, *World Water Balance and Water Resources of the Earth* (Leningrad, 1974).
c. L'vovich, *Global Water Resources and the Future* (Moscow, 1974).
d. P=Precipitation; E=Evaporation; R=Runoff.
e. Values are adjusted upward to include Antarctica for comparison with corresponding volumes derived by the other two authors.
Source: U.N. Water Conference, 1978, Reference 5.

Figure 8.2 Global Water Surplus and Deficiency[a] (millimeters per year)



Note: a. Defined as difference between annual precipitation and evapotranspiration. Evapotranspiration corresponds to the water demand from a potential crop not suffering from water deficiency.
Source: Falkenmark, 1977, Reference 3.

increased and competing demands have reached critical levels, especially in countries such as Israel, Egypt, Kenya, and even Poland (which is not an arid country). Table 8.3 shows total and per capita water availability for some selected countries (7). Large tropical nations like Brazil and large temperate countries like Canada have an abundance of freshwater: some 38,280 cubic meters (m^3) per person per year and 122,000 m^3/person/year, respectively, while large dry countries like Egypt have only 1,200 m^3 per person, most of it from the Nile River. Although the data show that the 13 countries listed as "Water-Rich" have no real problems with total water availability, it tells nothing about the distribution of freshwater within these countries, or its quality and utility for human use. Thirteen countries have been placed on the list of "Water-Poor countries." It should be noted that most of sub-Saharan Africa and the Middle East have chronic water shortages, as do parts of large countries like the United States, Australia, and the Soviet Union.

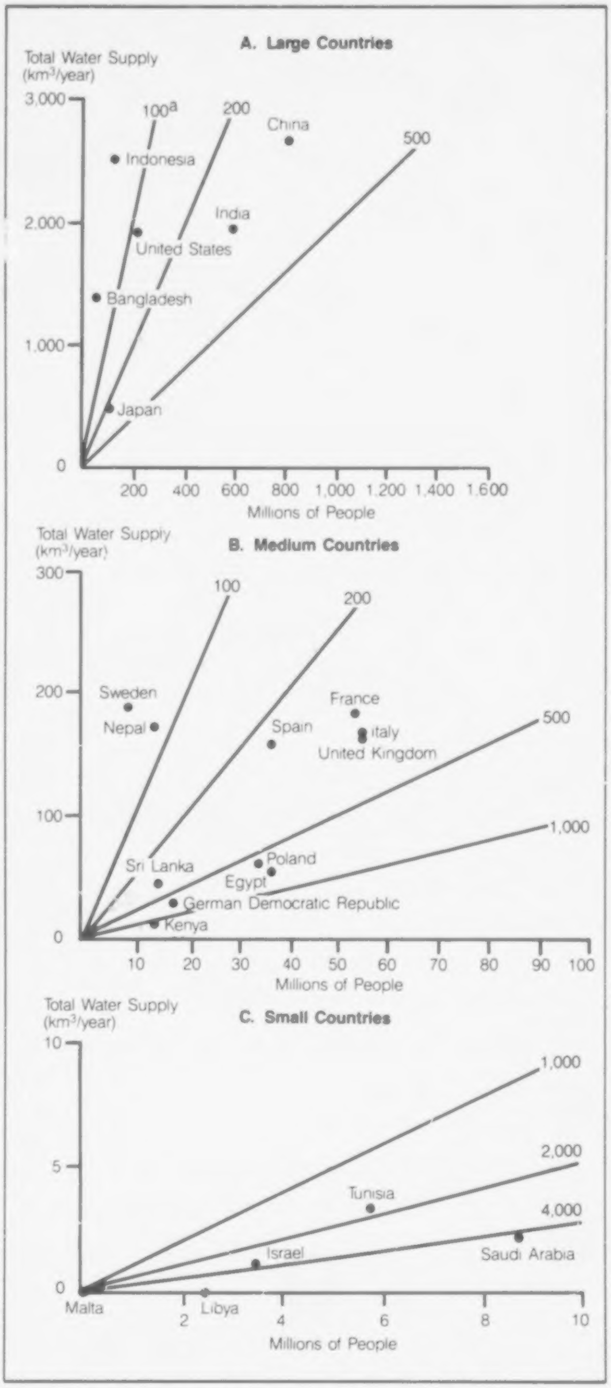
Figures 8.3A, B, and C show another way to look at the problem of population size and water availability. In water-short countries like Tunisia and Saudi Arabia, 2,000 and 4,000 people, respectively, compete for every 1 million cubic meters of water on a yearly basis. In relatively

Table 8.3 Total and Per Capita Water Availability in Selected Countries, 1985

	Total (km^3/yr)	Per Capita (thousand cubic meters per year)
Water-Rich Countries		
1 Canada	3.122	121.93
2 Panama	144	66.06
3 Nicaragua	175	53.48
4 Brazil	5.190	38.28
5 Ecuador	314	33.48
6 Malaysia	456	29.32
7 Sweden	183	22.11
8 Cameroon	208	21.41
9 Finland	104	21.33
10 USSR	4.714	16.93
11 Indonesia	2.530	15.34
12 Austria	90	12.02
13 United States	2.478	10.43
Water-Poor Countries		
1 Malta	0.025	0.07
2 Libya	0.700	0.19
3 Barbados	0.053	0.20
4 Oman	0.660	0.54
5 Kenya	14.800	0.72
6 Egypt	56.000	1.20
7 Belgium	12.500	1.27
8 South Africa	50.000	1.54
9 Poland	58.800	1.57
10 Haiti	11.000	1.67
11 Peru	40.000	2.03
12 India	1,850	2.43
13 China	2,680	2.52

Source: Forkasiewicz and Margat, 1980, Reference 7.

Figure 8.3 Global Comparison of Water Competition in Three Groups of Countries



Note: a. Numbers at ends of lines represent the numbers of people competing for 1 million cubic meters of water per year.
Source: Falkenmark, in press, 1986, Reference 9, based on data from Reference 7.

water-abundant countries like France, Italy, and England, only about 350 people are competing for the same amount (8). Some experts contend that once the number of individuals depending on one flow unit (i.e. 1 million cubic meters of water per year) increases above 2,000, the country is likely to suffer from inherent water deficit problems (9).

Figure 8.4 compares the water-short region of Africa with that of the western United States (10). The shaded areas show where the annual precipitation minus evapotranspiration is between 0 and 10 millimeters a year. The African belt of water-short countries corresponds fairly accurately with the "hunger belt" that cuts a wide swath through sub-Saharan Africa, extending into southern Africa. (See Box 8.1.) Although both regions suffer from chronic water deficits, the western United States compensates for this by utilizing groundwater resources and employing vast water basin transfer schemes, thereby making desert land productive.

Variability of Rainfall

Figure 8.5 depicts the areas of the world with the highest interannual variability of rainfall. North and sub-Saharan Africa, the Arabian peninsula, southern Iran, Pakistan, and western India mark the largest contiguous region with the highest variability of rainfall—more than 40 percent—over the long-term average. This high percentage is also the norm for the southwestern United States and northwestern Mexico, southwest Africa, the very eastern tip of Brazil, and parts of Chile. In these regions the amount of rainfall every year is highly unpredictable (11).

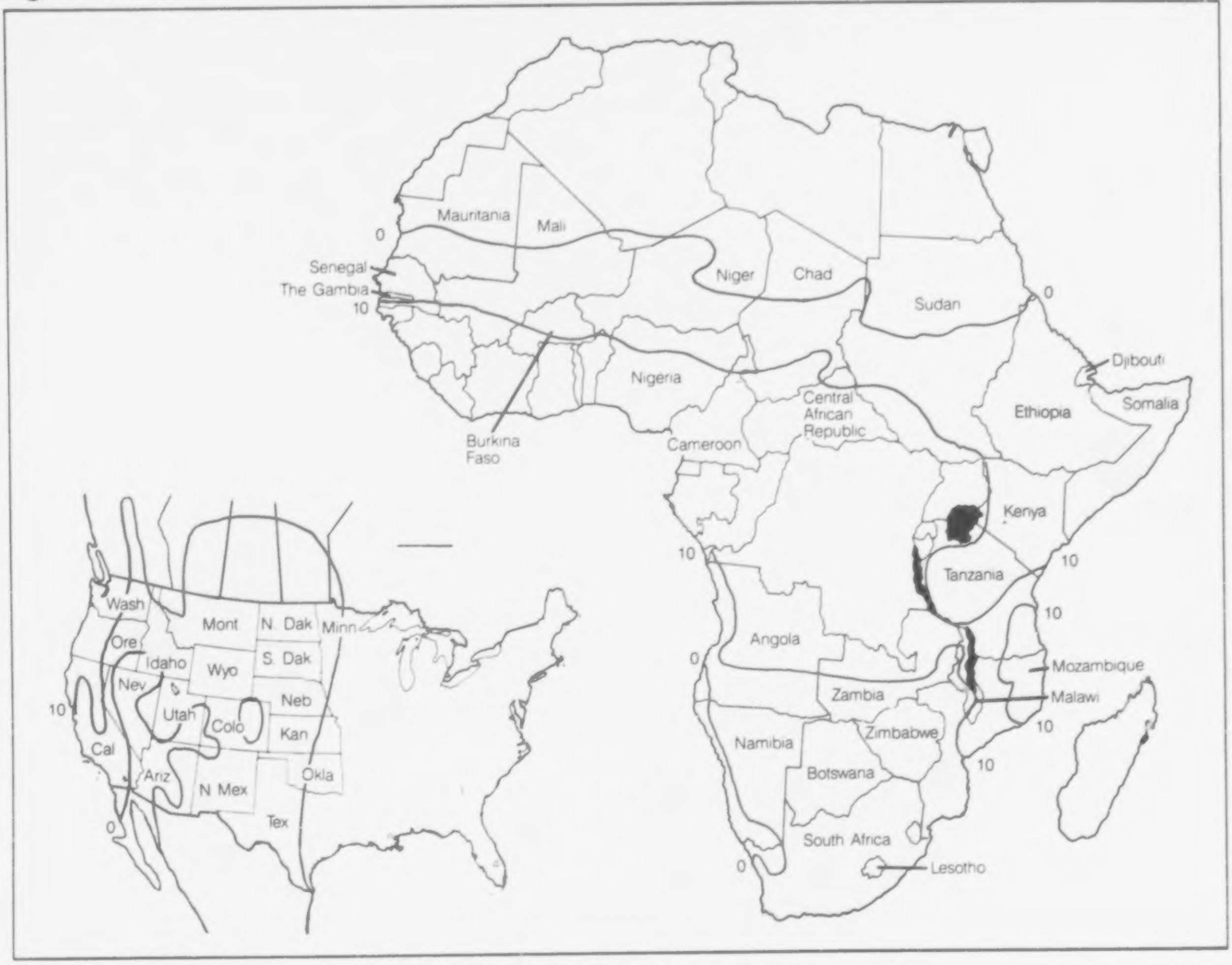
In the Sahel, not only is much of the rainfall "unreliable," but there is less of it today than 50 or even 30 years ago. Recent data indicate that there has been a significant downward trend in the actual amount of rain falling over much of Sahelian Africa (12). At one measuring station in Mali, for example, the mean amount of rainfall during a 50-year period from 1934–83 was 715 millimeters (mm), while during the last 15 years (from 1968–83) the mean amount of precipitation was only 577 mm a year (12). The same is true for measuring sites in Senegal, Burkina Faso, and Niger. (See Table 8.4.) Such cycles of drought have always been a common feature of this region.

In other parts of Africa the picture is not much different. In East Africa (Kenya, Tanzania, Uganda, Rwanda, and Burundi), rainfall also varies significantly from year to year. It is not unusual for a rainy season to be delayed or not appear at all. In fact, the highest annual total rainfall in any single year in the region can be "as much as four times the lowest recorded total" (13).

Stable Runoff

Some 41,000 cubic kilometers (km^3) of water flow off the land every year into the sea, but only the stable part of this runoff—some 9,000 km^3—can be economically

Figure 8.4 Areas of Africa and North America with Poor Water Availability


Mauritania
Mali
0
Senegal
The Gambia
10
Niger
Chad
Sudan
0
Djibouti
Somalia
Ethiopia
Nigeria
Central African Republic
Cameroon
Burkina Faso
Kenya
10
Tanzania
10
10
Angola
0
Mozambique
Malawi
Zambia
10
Zimbabwe
Namibia
Botswana
10
South Africa
Lesotho
0
Wash
Ore
Idaho
Mont
N. Dak
Minn
S. Dak
Wyo
Nev
Utah
Colo
Neb
Kan
Cal
10
Ariz
N Mex
Okla
Tex
0

Note: In the shaded areas, precipitation minus evapotranspiration is between 0 and 10 millimeters per year.
Source: Baumgartner and Reichel, 1975, Reference 10.

tapped for human use (14). The tropical regions of Latin America and Asia have the largest amounts of total runoff. Asia seems to have the biggest share, ranging from 12,200 km^3 to 14,100 km^3 (15). (See Table 8.2.) However, when measured by the average depth of runoff, Latin America leads with up to 685 mm a year compared with Asia's highest estimate of 324 mm. This is not unusual, given the fact that Latin America's average annual precipitation is 1,500 mm, 50 percent greater than the world average of 970 mm (16).

The volume of runoff in Africa, Australia, Europe, and North America combined is less than 40 percent of the total (17).

Of the nearly 41,000 cubic kilometers of net annual input into the continents, the stable runoff amounts to only about 13,000 km^3. However, since about 5,000 km^3 flows through sparsely populated regions, like the Amazon Basin, the total volume readily available for human use is whittled down to about 9,000 km^3 per year (18), of which the Soviet Union alone has 1,300 km^3 (19).

Although there appears to be no scarcity of water when viewed from the gross aggregate amount available—if water use doubles over the next 20 years, as some predict, and nothing is done to increase access to stable runoff or reduce demand through conservation measures—water scarcities could develop even in "Water-Rich" regions. The total runoff also disguises glaring regional differences. For example, Africa's runoff per unit of land area is about one-fifth that of South America's (20). This situation is due largely to the lower amounts of precipitation that characterize Africa. However, if stable runoff is viewed solely from the point of view of per cap-

Box 8.1 The African Drought — An Object Lesson in Fundamental Land/Water Interdependencies

The widespread "hunger crisis" that has ravaged sub-Saharan Africa since 1983–84 was scarcely unpredicted—scientists had been sounding alarm bells for years that an ecological disaster was going to strike Africa. It was predictable that the famine developed precisely in the zone where large-scale land degradation has been increasing in intensity and extent over the past decade (See Figure 8.4, main text). In this region, where precipitation minus evapotranspiration equals only 0–10 millimeters a year, groundwater recharge is extremely irregular, rendering water supplies in wells sensitive to even short periods of drought (1).

ZONE OF RECURRENT WATER SHORTAGES

Large parts of tropical and subtropical Africa are arid or semi-arid. Often the monthly rainfall is barely enough to support plant cover. Much of the continent suffers from a devastating interannual variability of rainfall (2). (See Figure 8.5, main text.) Typically, the variability is on the order of 30–40 percent for sub-Saharan Africa (3). This means that drought is part of the typical climatic picture. Evidently, agriculture in semi-arid Africa is somewhat like a water "lottery" (4). Crop success depends to a large extent on the capacity of local populations to manage the risks involved. And the risks are formidable. As Table 1 shows for Mali, in the 100 millimeter (mm) rainfall zone, there is never as much as four months of pasture, in dry years perhaps only one or two months. Even in the 600 mm zone, there is a risk of crop failure during dry years (5).

The importance of rainfall variability has been repeatedly stressed by scientists in the past decade. However, the habit ingrained in "northern" scientists to talk about "normal precipitation" in the South is seriously misleading when applied to dry areas like Africa, where "normal" has a completely different meaning. Multi-year recurrent droughts are normal for this region—in fact there have already been three of them during this century (6). And the last 15-year period has been characterized by a persistent rainfall deficit, when compared to the long-term average. The "wet" 1960s have been followed by nearly two decades of relatively dry years.

FROM DROUGHTS TO DISASTERS

The Sahelian region is a classic case of human mismanagement of the environment. Traditional "risk management" in this drought-prone area used to be a largely nomadic way of life. People and their animals moved south during the dry season in order to find adequate pasture. In the 1960s, countries in the Sahelian region were given foreign aid and loans from international development agencies to launch many well-drilling projects in the belief that social development would benefit from access to water year-round. In the wake of the wells, the presence of easily accessible water encouraged a sedentary way of life and in some cases, where there was sufficient pasture, the traditional southward migration was abandoned. This change, in turn, resulted in the rapid deterioration of pasturelands around the wells.

Today, the drought-prone areas of the Sahel are occupied by both sedentary farmers and nomadic pastoralists, and during dry years, overgrazing is a serious problem throughout the entire region. The potential biomass production of the area, which determines the carrying capacity of the land, and therefore places limits on the size of the human and animal populations that can be sustained, has often been surpassed. A German scientist based in Mali for 26 years has described the land degradation process, using three examples (7). In Central Gourma in east Mali, the "desertification" of large tracts of once arable land was accelerated ironically by the installation of water wells. Although a vigorous pasture rotation policy was implemented, initially to control the risk of overgrazing, the system soon collapsed and the wells are now used year-round. As a result, the desert has moved 350 kilometers south over the past 20 years. In central Niger, a vast area nearly the size of West Germany has been seriously degraded due to a similar process. Water wells were drilled, which altered the migration patterns, placing increasing stress on the carrying capacity of this fragile water-short region. The situation was aggravated by the rainfall deficiencies of the last 15 years. Similar conditions exist over wide areas in Senegal and southwest Mauritania, where the "well euphoria" of the 1960s has caused disasters, best described by a frequently used expression in the Sahelian countries: "Where there is plenty of water, there is no grass; where there is plenty of grass, there is no water" (8).

DISASTER RELIEF STRATEGIES COLLAPSING

Even if droughts are a naturally recurrent pheonomena in all countries with a dry season climate (both semi-arid and semi-humid), they tend to develop into disasters in areas with high population densities, although sparsely populated regions with degraded carrying capacities are also severely affected (i.e., parts of Mali and Chad). In such areas, dry years reduce the amount of food available to subsistence farmers to a bare minimum, even if there is water in the wells.

An analysis of such "natural" disasters, carried out by the Swedish Red Cross, shows that they are triggered by a chain process, rather than one event (9). Widespread drought forces people off the land and into relief centers or refugee camps. Massive population concentrations in the camps soon foster chronic shortages of food and water.

Traditionally, disaster relief took the form of emergency assistance, directed largely toward reducing human suffering and hunger. The general philosophy of relief was to aid the stricken populations momentarily, until "normal" conditions returned. In other words, it was a question of helping the victims back to a viable *status quo*. The present continuing crisis in sub-Saharan Africa has highlighted the fact that there is no longer a "normal" condition to return to; overpopulation and short-sighted land use policies have combined to make the disaster a continuing one.

Table 1 Fluctuating Length of Growing Season in Southern and Central Mali

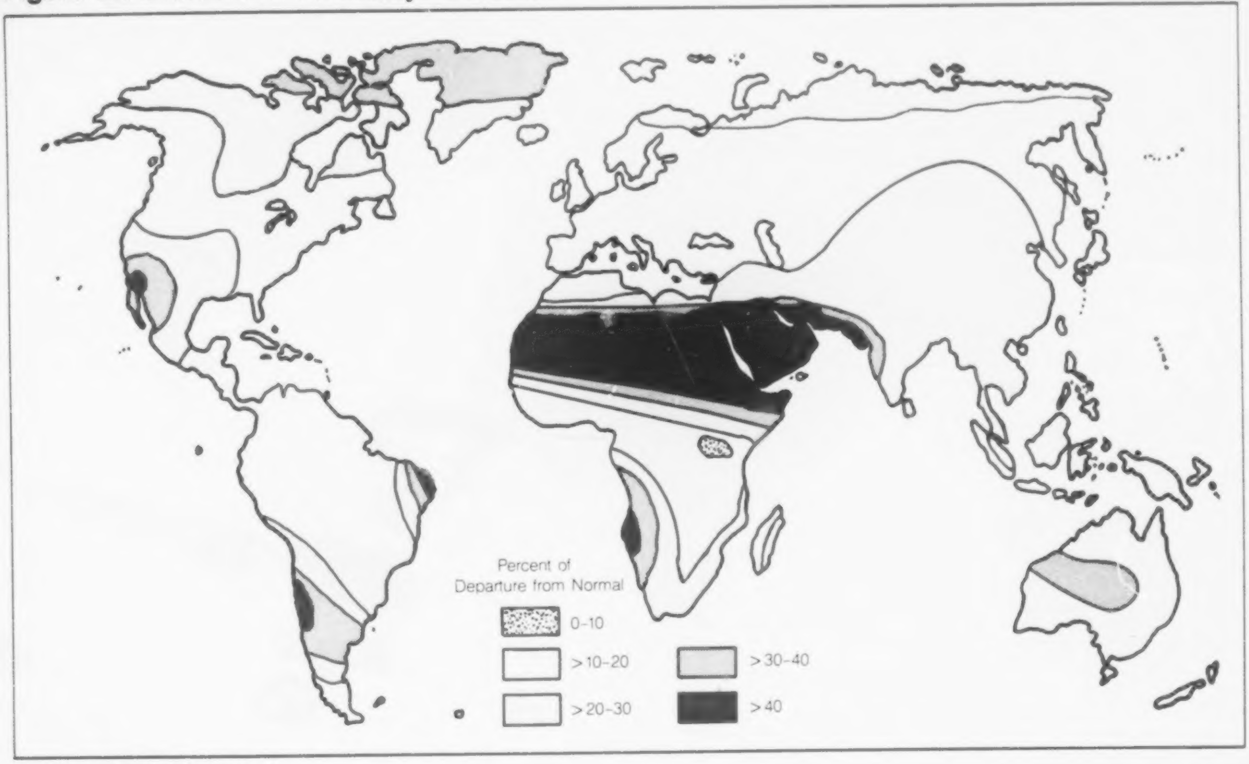
Station	Long-Term Annual Rainfall mm/yr	Length of Growing Season: Normal (Dry) Years (99 years of 100) Pasture	Crop	Extremely Wet Years (1 year out of 100) Pasture	Crop
Bougouni	circa 1200	190	150	250	210
Nioro	circa 600	110	70	220	170
Kidal	circa 100	30	10	100	50

Source: Diawara, 1984, Reference 5.

References and Notes

1. M. Falkenmark, "Macro-Scale Water Supply/Demand Comparison on the Global Scene—A Hydrological Approach," in *Hydrology and Earth Sciences*, R. Keller, Ed. (Beitrage zur Hydrologie, 1986, in press); and A. Baumgartner and E. Reichel, *The World Water Balance* (Elsevier, Amsterdam, 1975).
2. Y. Gustafsson, "Variations in Rainfall as a Natural Constraint on Agriculture," *AMBIO*, Vol. 6, No. 1, p. 34 (1977); and A.K. Biswas, "Climate and Development," in *Climate and Development*, Vol. 13, A.K. Biswas, Ed. (Tycooly International Publishing Ltd., Dublin, 1984).
3. A.K. Biswas, "Climate and Water Resources," in *Climate and Development*, Vol. 13, A.K. Biswas, Ed. (Tycooly International Publishing Ltd., Dublin, 1984).
4. M. Falkenmark, "Macro-Scale Water Supply/Demand Comparison on the Global Scene—A Hydrological Approach," in *Hydrology and Earth Sciences*, R. Keller, Ed. (Beitrage zur Hydrologie, 1986, in press).
5. A. Diawara, *A Rainfall Generator and Water Balance Model for Mali* (Royal Institute of Technology, Stockholm, Bulletin No. TRITA-VBI-121, 1984).
6. J. Sircoulon, "Les Données Hydropluviometriques de la Sécheresse Récente en Afrique Intertropicale. Comparison avec les Sécheresses 1913 et 1940," *Cahiers de e' O.R.S.T.O.M. serie Hydrologie*, Vol. 13, No. 2 (1976).
7. R. Reichelt, *Die Desertifikation Sudlich der Sahara, Ursachen und Folgen* (Manuscript CILSS, Ouagadougou, Burkina Faso, 1984).
8. *Ibid.*
9. Swedish Red Cross, *Prevention Better than Cure, Report on Human and Environmental Disasters in the Third World* (Swedish Red Cross, Stockholm and Geneva, 1984).

Figure 8.5 Interannual Variability of Rainfall



Source: Biswas, 1984, Reference 11.

ita availability, then Asia has only one half of the world's average gross water availability, while Africa is almost exactly at the world average of 8,562 cubic meters per person per year (21).

In order to compensate for increasing demands on limited water resources, many countries—especially those in "Water-Poor" regions—are trying to capture a larger share of the gross runoff. By the end of 1978, for example, the Peoples Republic of China had constructed some 84,000 reservoirs with a total storage capacity of 400 billion cubic meters (22).

The Soviet Union has also increased its accessible stable runoff by building dams and reservoirs so that its total now stands at 16,930 cubic meters per person per year (23).

One crucial element in securing future water supplies is the ability of countries, especially those in water-scarce areas, to increase their access to stable runoff by building dams and reservoirs, tapping groundwater reserves, and learning to use existing reserves in a more sustainable fashion.

Groundwater: The Resource

The amount of water stored in the ground is enormous—between 4 and 60 million cubic kilometers—exceeding the amounts in rivers, lakes, reservoirs, swamps, marshes, and the atmosphere combined. (See Table 8.1.) However, if water above 4,000 meters depth is included, this estimate narrows to between 8 and 10 million km^3 (24). But only a very small portion of this water is economically exploitable. So despite the great quantities of groundwater available, relatively little of it has actually been tapped. Part of the problem is that in much of the Third World, the extent and quality of groundwater supplies are unknown and so too are the costs and types of technology needed to extract it. In Central America, for example, the most abundant amounts of groundwater are thought to be in Nicaragua and Costa Rica, although both Guatemala and El Salvador have significant reserves in their Pacific coastal lowlands (25). Nevertheless, very few systematic data on the region's aquifers are available. The same is true for South America, Africa, and large parts of Asia.

Recent trends suggest that groundwater will be increasingly exploited during the next 20 years, especially in North America, unless pumping costs escalate to the point where it becomes uneconomical to tap groundwater reserves. (See "Emerging Trends in Water Use," below.)

WATER USE DRIVES HUMAN ACTIVITIES

Water use is another area saddled with rather poor statistics, even in countries with otherwise good statistical data bases. When industrial and agricultural demand for water increases, pressures build on limited resources. As can be seen in Figure 8.6A, total global water use has increased rapidly since about 1950, while per capita water use has

Table 8.4 Mean Annual Rainfall in the Sahel
(millimeters)

Country	Station	Mean Amount From Reference Sources: WMO[a]	Wernstedt[b]	Lebedev[c]	Mean Amounts During the Last: 50 years (1934-83)	40 years (1944-83)	30 years (1954-83)	15 years (1968-83)	Last 30 Years As Percentage of the Reference Sources	Last 16 Years As Percentage of the Reference Sources
Senegal	St. Louis	347	390	389	313	296	281	233	72-81	60-67
	Podor	X	311	309	285	276	258	200	83	64-65
	Matam	X	527	520	462	431	411	314	78-79	60
	Linguere	535	533	531	462	449	418	358	78-79	67
	Dakar	578	599	578	500	481	458	329	76-79	55-57
	Diourbel	X	650	660	628	619	589	482	89-91	73-74
	Kaolack	X	823	830	X	X	655	535	79-80	64
	Tambachounda	942	886	880	879	839	826	709	88-94	75-81
	Kedougou	X	1,307	1,307	1,238	1,226	1,239	1,147	95	88
	Kolda	X	1,215	1,217	X	X	1,126	963	93	79
	Ziguinchor	1,547	1,559	1,553	X	X	1,347	1,133	86-87	73
Mali	Kayes	821	750	748	715	708	657	577	80-88	70-77
	Nioro	631	709	707	548	544	518	412	73-82	58-65
	Mopti	552	540	541	511	512	495	458	90-92	83-85
	Hombori	454	390	410	402	409	390	353	86-100	78-91
	Gao	261	271	271	235	236	225	200	83-86	74-77
	Menaka	263	249	251	256	260	250	202	95-100	77-81
	Tomboctou	225	201	208	X	X	X	147	X	65-73
	San	743	749	746	738	741	737	683	98-99	91-92
	Segou	724	702	706	688	679	680	590	94-97	81-84
	Bamako	1,099	1,075	1,000	983	964	949	869	86-95	79-87
	Kita	1,151	1,116	1,116	X	X	X	882	X	77-79
	Kenieba	1,408	1,353	1,287	X	1,248	1,228	1,083	87-95	77-84
	Bougouni	1,337	1,311	1,316	1,246	1,193	1,186	1,082	89-90	81-83
	Koutiala	1,022	982	982	989	996	963	859	94-98	84-87
	Sikasso	1,329	1,373	1,376	1,221	1,210	1,189	1,144	86-89	83-86
Burkina Faso	Dori	542	483	501	X	X	533	456	98-110	84-94
	Ouahigouya	715	728	706	686	664	641	572	88-91	79-81
	Dedougou	X	975	991	893	872	846	738	85-87	74-76
	Ouagadougou	879	881	879	835	837	846	796	96	90-91
	Fada N'Gourma	890	890	834	878	899	911	824	102-109	93-99
	Boromo	1,029	1,079	1,029	951	938	911	889	84-89	82-86
	Bobo Dioulasso	1,185	1,181	1,134	1,116	1,130	1,095	1,028	92-97	87-91
	Gaoua	1,161	1,162	1,247	1,103	1,059	1,062	1,036	85-91	83-89
Niger	Tahoua	407	385	385	394	404	396	336	97-103	83-87
	Tillabery	510	500	500	X	X	X	376	X	74-75
	Niamey Aero	636	594	582	575	576	570	516	90-98	81-89
	Birni N'Konni	597	602	601	X	X	517	464	86-87	77-78
	Maradi	642	622	623	565	561	539	454	84-87	71-73
	Zinder	549	530	515	486	479	460	401	84-89	73-78
	Magaria	X	617	616	X	599	587	500	95	81
	Maine Soroa	404	412	418	X	X	374	324	89-93	78-80
	N'Guigmi	236	213	212	222	229	228	192	97-108	81-91
	Gaya	X	861	852	X	828	818	803	96	94

X = not available
Notes:
a. World Meteorological Organization (WMO), *Climatological Normals (CLINO) for Climate and Climate Ship Stations for the Period 1931-1960* (WMO, Geneva, 1971).
b. F.L. Wernstedt, *World Climatic Data* (Climatic Data Press, Lemont, Pennsylvania, 1972).
c. A.N. Lebedev, Ed., *The Climate of Africa, Part I, Gidrometeoizdat In Russian* (Leningrad, 1968).
Source: Todorov, 1985, Reference 12.

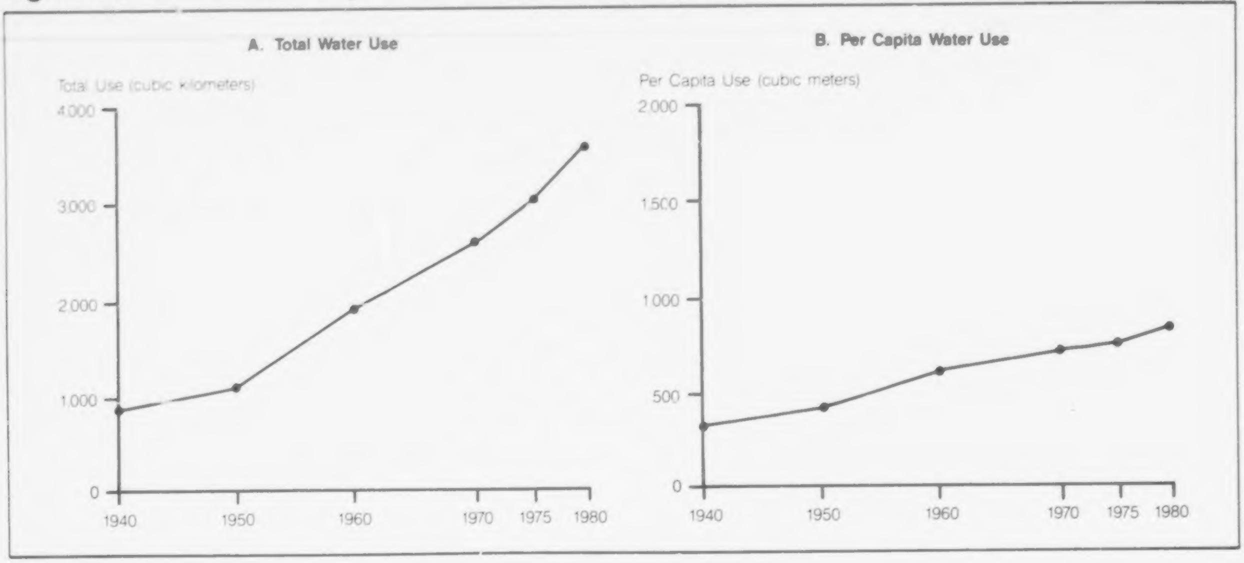
steadily risen over the same period. (See Figure 8.6B.) Table 8.5 shows the estimated water use in selected countries, distinguishing among public (municipal), industrial, electric cooling, and agricultural withdrawals. As expected, the United States leads in water withdrawals with 472 cubic kilometers withdrawn every year (1.6 trillion liters per day, or 7,200 liters per person per day). The largest share of this water (49 percent) serves industry and electricity-generating plants (nuclear and fossil-fueled). Compare these figures to data for India, which withdraws 380 cubic kilometers per year, or a little more than 1 trillion liters per day, but because of the large population, this impressive figure amounts to only 1,500 liters per person per day, with 93 percent of it withdrawn for irrigation (26).

According to the United Nations Environment Program (UNEP), global water use breaks down into three broad categories (estimated in rough annual percentages): irrigation (73 percent), industry (21 percent), and public uses (6 percent) (27). Water use patterns differ significantly from North to South. In the developed countries, industries account for 40 percent or more of all water use (in Eastern Europe industries can guzzle up to 80 percent), while in the Third World, the overwhelming bulk of water goes for irrigation, with industry seldom accounting for even 10 percent (28). These trends are likely to continue into the next century.

It should be noted that Asia and North America (United States and Canada) withdraw about the same amount of water for public and household purposes (both urban and rural), but considering North America's population of 263 million compared with Asia's total of 2.6 billion, its per capita use of public water supplies is much higher than Asia's. North America uses the greatest total amount of water for industrial purposes (29), while Asia leads all continents in the use of water for irrigation.

Increasing water withdrawals for municipal, industrial, and agricultural purposes, shown as a ratio of freshwater renewal, indicate the extent to which some areas, particularly North and sub-Saharan Africa and the Middle East, were already coming close to their limits a decade ago (1975) (30). (See Figure 8.7.) Today, some 256 million peo-

Figure 8.6 Total and Per Capita Global Water Use, 1940–80



Sources:
1. Falkenmark, 1977, Reference 3.
2. Postel, 1985, Reference 26.

ple live in regions where 50–100 percent of the stable runoff is used.

Public Water: Drinking Water and Sanitation

Most public uses (31) of water fall within the categories of drinking water, household water, and water for sanitation and sewage systems (although most statistics include commercial use in this category as well). Overall, only a small percentage of total water withdrawals—some 5–6 percent globally—is used for public (municipal) purposes, but the quality of this water is very important (32). The World Health Organization (WHO) estimated in 1980, that three out of five people in developing countries did not have easy access to safe drinking water and three out of four persons in these countries had no kind of sanitary facility—not even a pit or bucket latrine (33). As many as 1.8 billion people are exposed to diseases by drinking contaminated (non-potable) water (34). Every day throughout the world some 25,000 people die from a combination of factors related mostly to using contaminated water; four out of five deaths of children in developing countries are due to water-related diseases (35).

According to WHO, 71 percent of the urban dwellers in 55 selected Third World countries had access to clean drinking water in 1980, as opposed to only 32 percent of the rural populations in 61 developing countries (36). In those same countries a wide gulf also separates urban and rural populations when it comes to having access to sanitation facilities: 41 percent of the urban population was served by some form of sanitation facility, as opposed to 12 percent of the rural population (37).

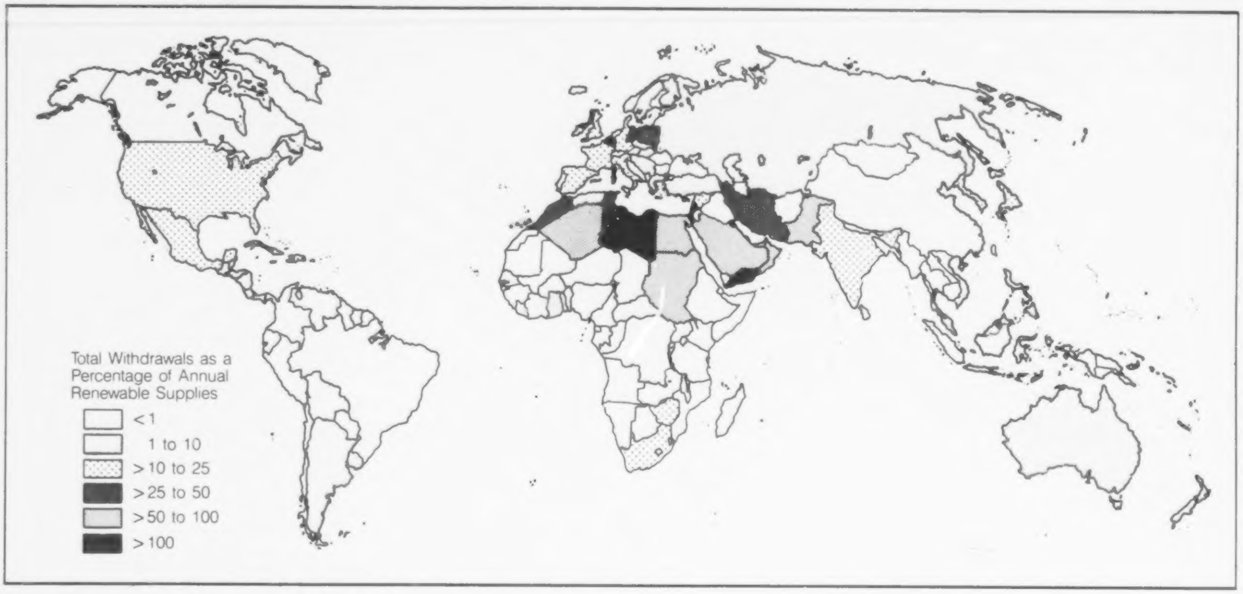
Table 8.5 Average Annual Water Use in Selected Countries, Total and Per Capita

	Water Withdrawal		Share Withdrawn by Sector (percent)			
Country	**Total (km^3)**	**Per Capita (m^3)**	**Public**	**Industry**	**Electric Cooling**	**Agriculture/Irrigation**
United States	472.000	1,986	10	11	38	41
Canada	30.000	1,172	13	39	39	10
Egypt	45.000	962	1	0	0	98
Finland	4.610	946	7	85	0	8
Belgium	8.260	836	6	37	47	10
USSR	226.000	812	8	15	14	63
Panama	1.300	596	12	11	0	77
India	380.000	499	3	1	3	93
China	460.000	460	6	7	0	87
Poland	15.900	423	14	21	40	25
Libya[p]	1.470	408	17	0	0	83
Oman	0.043	350	2	0	0	98
South Africa[p]	9.200	284	17	0	0	83
Nicaragua	0.890	272	18	45	0	37
Barbados	0.027	102	45	35	0	20
Malta	0.023	60	100	0	0	0

Notes:
p = Public and Industry
i = Industry and Electric Cooling

Sources:
1. For all data except China: Forkasiewicz and Margat, 1980, Reference 7.
2. For data on China: V. Smil, *The Bad Earth: Environmental Degradation in China* (Zed Press, London, 1984).

Figure 8.7 Index of Freshwater Use, 1975


Total Withdrawals as a Percentage of Annual Renewable Supplies
< 1
1 to 10
> 10 to 25
> 25 to 50
> 50 to 100
> 100

Source: Forkasiewicz and Margat, 1980, Reference 7.

In order to meet the International Drinking Water Supply and Sanitation Decade targets for clean water and sanitation by 1990, an additional 768 million rural residents in the Third World would have to be served with water supplies, and 322 million with sanitation facilities (38).

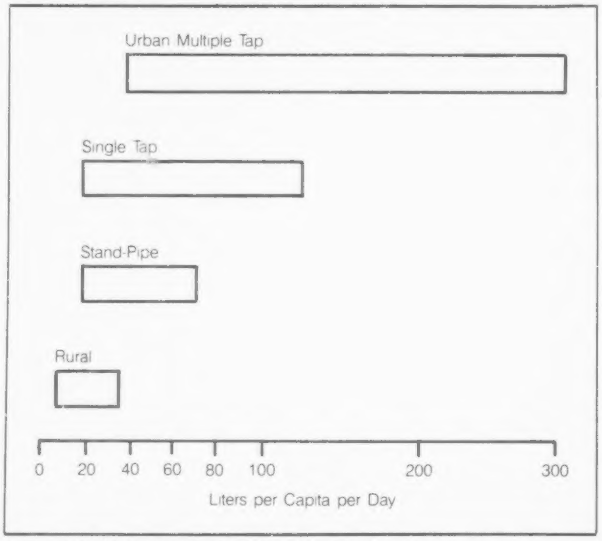
Figure 8.8 demonstrates how the amount of water used depends on the mode of distribution, income levels, and geographical location (39). Multiple urban taps result in a withdrawal of between 40 and 350 liters per person per day, while rural distribution in the Third World—water is usually hand-carried by women and children—ranges from near the biological minimum of 2–5 liters per person per day up to 40 liters, and the quality of the water varies considerably. Water-related diseases tend to occur when the availability of clean water falls below 50 liters per person per day. It should be noted that urban dwellers in most of the Third World have improved access to clean drinking water as compared to their rural counterparts. It has been estimated that more than 90 million rural residents of Latin America alone have little or no access to safe supplies of potable water (40). Similarly, 23,000 villages in India had no access to clean drinking water, as of 1982 (41).

A similar picture is seen throughout Africa: in rural Tanzania, for instance, only 28 percent of the people have access to safe drinking water, as opposed to 82 percent in the capital of Dar-es-Salaam (42). WHO data for 1980 show that in Kenya only 21 percent of the rural population was served with safe drinking water, while 39 percent of rural residents had access to sanitation facilities. For Madagascar the percentages were 9 percent and unknown, respectively, and for Angola 12 percent and 15 percent, respectively (43). The same pattern prevails over much of the rest of Africa.

Industry

In industry, water is used for cooling, processing, boiling, and transporting, in addition to air conditioning and cleaning. There is a great diversity among various types of industry in terms of both the amounts of water needed and its efficient use. A few industries, principally primary metals, chemical products, petroleum refining, pulp and paper, and food processing, account for a full

Figure 8.8 World Daily Household Water Use Per Capita, 1976



Source: U.N. Water Conference, 1978, Reference 5, p. 48.

two thirds or more of all industrial water withdrawals (44). The specific industrial processes used heavily influence the amount of water needed. An "inefficient" plant may use up to 20 times more water than an "efficient" one in manufacturing the same product (45).

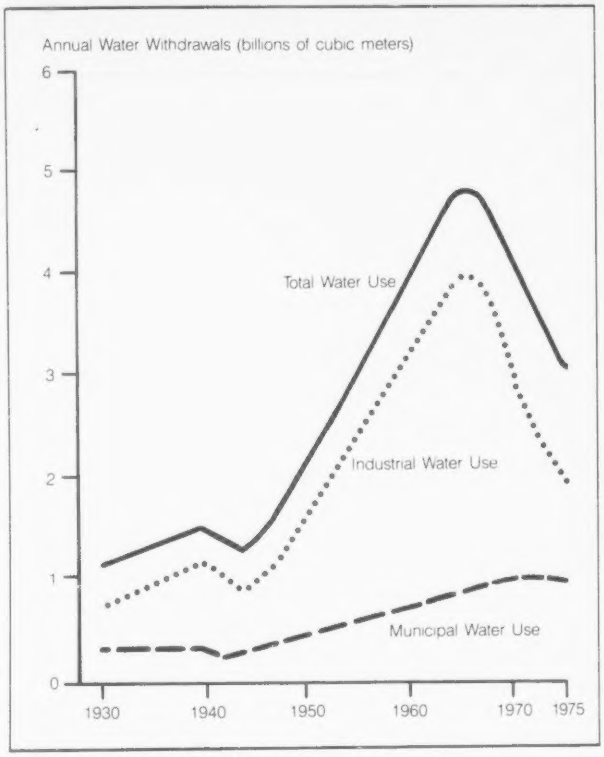
In a general sense, the heaviest industrial water users mentioned above have improved their water use efficiencies significantly over the past decade. In Japan, for example, total industrial water use increased from 50 million cubic meters in 1965 to 120 million cubic meters in 1974, but by the mid-1970s, two thirds of it was recycled water compared with one third in 1965 (46).

By 1975, U.S. industry as a whole had achieved a water recycling rate of 2.2. This means that water brought into the plant was used on average 2.2 times before it was discharged. And about 90.5 percent of the original water withdrawn was returned to the surface water system (47). West Germany has a similar recycling rate (2.0), as does Japan (1.5). Given the trend to recycle process water, some researchers have predicted that the industrial demand for water in the United States will actually decline from the current level of more than 1,500 liters per capita per day to less than 1,000 liters per capita per day by the year 2000 (48).

Some advanced industrial countries in Europe have also begun to decrease their industrial raw water demand. Swedish industries, for instance, were forced by water quality laws to re-circulate their process water, resulting in a rapid decline in industrial water demand (49). (See Figure 8.9.)

In the Third World, on the other hand, the trend is just the opposite; industrial water demands are increasing as countries struggle to expand their industrial base.

Figure 8.9 Municipal, Industrial, and Total Water Withdrawals in Sweden, 1930–75



Source: Falkenmark, 1977, Reference 49

FOCUS ON: IRRIGATION

Agriculture, mainly irrigation, accounts for the largest single share of global water use—some 73 percent (50). Although estimates vary widely (as do definitions of irrigated land), one recent reckoning puts the total world irrigated area at 271 million hectares with most of the recent increase in the European part of the Soviet Union, Asia, and South America (51). (See Table 8.6.) India has seen the most rapid growth. In the 1960s, the gross area under irrigation expanded from about 28 million hectares to 37 million hectares and today it stands at around 50 million hectares (52). (See also Chapter 4, "Food and Agriculture," Table 4.5.)

Despite the extensive use of irrigation to increase crop yields, especially in Asia, irrigation efficiencies are rather low. Farmers tend to over-irrigate because of low prices and cheap gravity systems, so it is not uncommon that 70–80 percent of the water withdrawn from a river for irrigation purposes never reaches its intended destination. Even in the Colorado River Basin in the southwestern United States, the efficiency of water use is below 50 percent (53).

Environmental Impacts

The two major environmental impacts from irrigation are: 1) the excessive use of groundwater in relatively dry areas, depleting aquifers; and 2) the improper design and management of irrigation projects, which can result in salinization, alkalinization, and waterlogging of fertile agricultural land.

Massive amounts of money have gone into the development of irrigated agriculture throughout the world. As a result, in certain areas where surface water is limited or legally difficult to use, groundwater reserves have been mined at a rate that exceeds their natural recharge. (See Table 8.7.) In North Africa and Saudi Arabia, socioeconomic development has been based, to a certain degree, on the use of fossil groundwater (which is essentially

Table 8.6 Growth in Irrigated Area by Continent, 1950–85

	Total Irrigated Area (million hectares)	Growth in Irrigated Area[a] (percent)		
Region	**1985**	**1950-60**	**1960-70**	**1970-80**
Africa	13	25	80	33
Asia[b]	184	52	32	34
Europe[c]	29	50	67	40
North America	34	42	71	17
South America	9	67	20	33
Oceania	2	0	100	0
World	**271**	**49**	**41**	**32**

Notes:
a. Percentage increase between 1970 and 1982 prorated to 1970-80 to maintain comparison by decade
b. Includes the Asian portion of the USSR
c. Includes the European portion of the USSR
Source: Adapted from Rangeley, 1985, Reference 51

Table 8.7 Selected Cases of Excessive Water Withdrawals

Region	Status
Colorado River Basin, United States	Yearly consumption exceeds renewable supply by 5 percent, creating a water deficit; Colorado River is increasingly salty; water tables have fallen precipitously in areas of Phoenix and Tucson.
High Plains, United States	The Ogallala, a fossil aquifer that supplies most of the region's irrigation water, is diminishing; over a large area of the southern plains, the aquifer is already half depleted
Northern China	Groundwater overdrafts are epidemic in northern provinces; annual pumping in Beijing exceeds the sustainable supply by 25 percent; water tables in some areas are dropping up to 1–4 meters per year
Tamil Nadu, India	Heavy pumping for irrigation has caused drops in water table of 25–30 meters in a decade.
Israel; Arabian Gulf; coastal United States	Intrusion of sea water from heavy pumping of coastal aquifers threatens to contaminate drinking water supplies with salt.
Mexico City; Beijing, China; Central Valley, California; Houston-Galveston, Texas	Groundwater pumping has caused compaction of aquifers and subsidence of land surface, damaging buildings, streets, pipes, and wells; hundreds of homes in a waterfront Texas community have been flooded.

Source: Adapted from Postel, 1985, Reference 26

non-renewable), since surface water is scarce and in some cases unusable (54). Globally, roughly only 0.1 percent of the total reserves of groundwater are rechargeable and can therefore be exploited on a sustainable basis (55). In addition to such limited availability, there are severe stresses on its quality.

In the southwest United States, the failure to place water on a sustainable footing threatens the viability of the resource base and consequently the economic system dependent upon it (56). Degraded aquifers have been reported from all over the continental United States. (See Figure 8.10.) And there is growing concern that large areas of irrigated agriculture throughout the western half of the country will collapse, unless water management strategies are worked out in combination with agricultural techniques better suited to drier climates. One fifth of the irrigated cropland in the United States is supported by groundwater mined from the vast Ogallala aquifer, which underlies portions of eight states on the high plains (57). (See Table 8.7.)

Excessive groundwater pumping has been reported from many other parts of the world as well. In the Tamil Nadu state of India, the groundwater table has plunged by over 25 meters since the 1930s (58). Likewise, in northern China, around Beijing, groundwater supplies have been overdrawn by 25 percent above the renewable supply, dooming plans to increase agricultural production (59).

During the 1960s, scientists generally became aware of the large amounts of chemical compounds generated by badly planned and executed irrigation projects, as well as by certain industrial uses. The mismanagement of irrigation schemes, in particular, leads to the "sterilization" of some of the best and most productive soils (60). This has been a persistent problem, even in such highly developed regions as the San Joaquin Valley of California. Unfortunately, the frequent decision to postpone the construction of expensive drainage systems to a later stage of an irrigation project means that short-term financial constraints get transformed into long-term, even more expensive resource degradation problems.

Globally, some 1–1.5 million hectares of mostly prime agricultural land are salinized every year (61). Since the beginning of modern civilization, the total amount of land affected by salinization from both anthropogenic and natural factors has been estimated at 20–30 million hectares (62).

In the United States alone, it is reckoned that 20–25 percent of all irrigated land (some 4 million hectares) suffers from salinization (63). And it is a persistent problem in the plains of eastern and western China, the Indian sub-continent, Central Asia and Asia Minor, the Aral-Caspian lowlands, the Caucasus and southeastern Europe, the Middle East, North and West Africa, and the plains of North and South America.

The best irrigation water from rivers still contains 200–500 milligrams per liter (mg/l) of salts. Supplying 10,000 cubic meters of water deposits in the soil anywhere from two to five tons of salt per hectare of land. After 10–20 years of irrigation the salt load becomes enormous, amounting to dozens and even hundreds of tons per hectare, rendering the land unfit for agricultural production (64).

This process of salinization can become a "vicious cycle." When water is diverted from a river or stream for irrigation, as much as 50 percent of it is not used by the crops. Instead, it seeps out of unlined canals, pipes, and ditches, runs off fields, or percolates through the soil. Most of this water eventually finds its way back to a river or to groundwater reservoirs. On its way through the soil, water dissolves naturally occurring salts in the rocks and soils and carries it along to rivers or groundwater aquifers, increasing their salinity. In the Colorado River Basin, for example, irrigation causes nearly 85 percent of all "man-induced salinity" (65).

Repeated and excessive use of water for irrigated crops also results in the eventual accumulation of salts in the upper layers of the soil, particularly if the irrigation water itself contains elevated amounts of salt. However, to maintain crop yields, these salts must be leached out of the root zone.

In order to avoid salt accumulation in the soil, the input of salts from the irrigation water must be balanced by a corresponding outflow of salts with the drainage water from the irrigated land (66). Drainage is also important because irrigated land often suffers from rising water tables. A balance has to be maintained in order to avoid waterlogging due to the accumulation of groundwater in the root zones of the crops. By keeping the groundwater level deep enough, evaporation near the surface, which contributes to salinization, can be prevented.

Lack of adequate drainage in irrigated lands remains one of the most serious problems: waterlogging of the soil is as damaging as salinization and they often go hand in hand. By 1990, an estimated 890,000 hectares of highly productive land in the San Joaquin Valley of California will have water tables a mere 1.5 meters deep, requiring that some 650,000 hectares be drained properly in order to remain productive (67). Rising water tables constitute a persistent problem for irrigated agriculture, but proper drainage schemes can usually eliminate waterlogging.

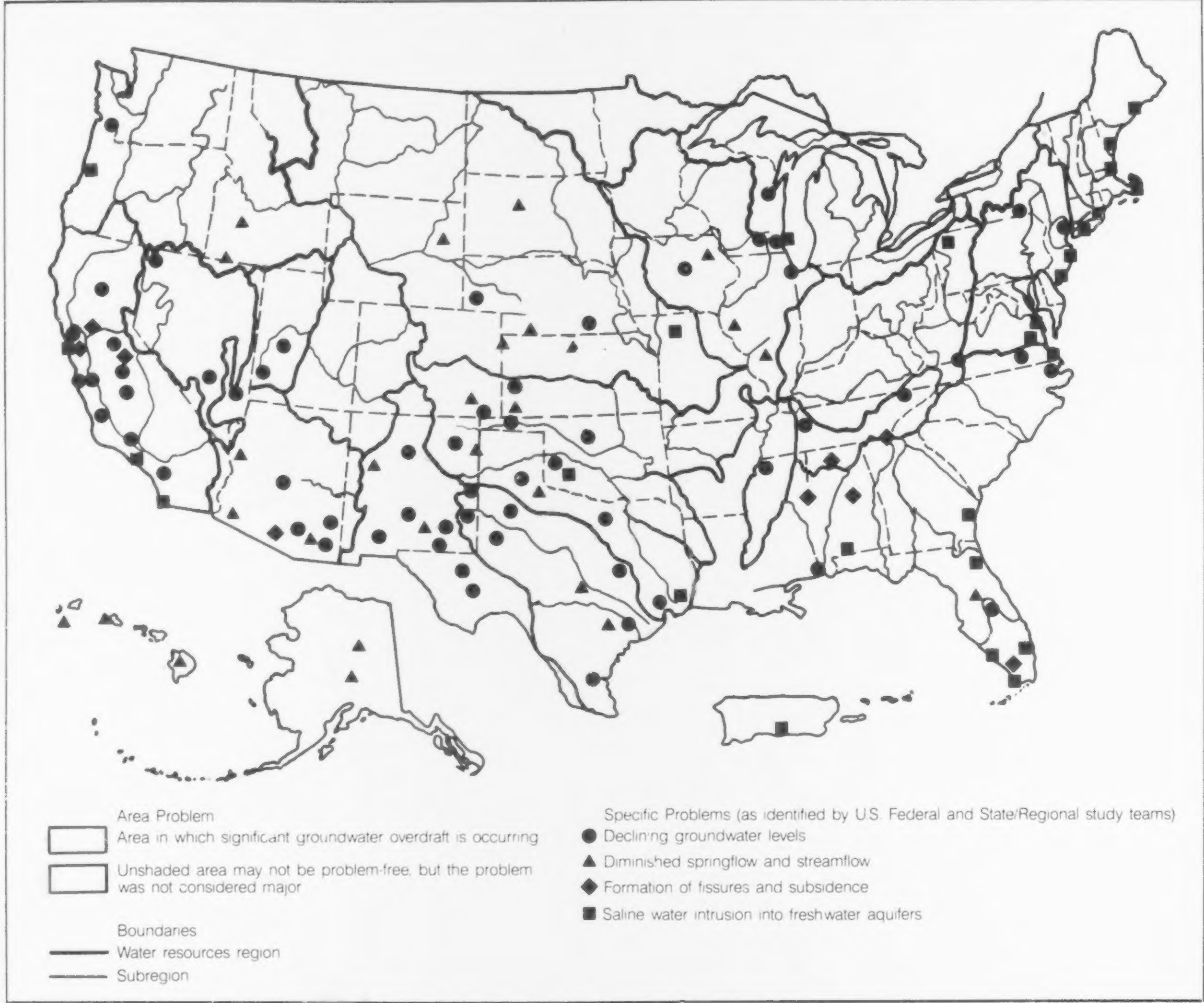
In the Colorado River Basin (southwestern United States), large amounts of excess irrigation water have added to the increasing salinization of the river itself (68). Increased salinity at the Mexican border led to a confrontation between the United States and Mexico, which eventually forced the United States to construct a desalinization plant at the border (69). Salt damage in the U.S. part of the Colorado River Basin still costs all users more than $113 million a year (70).

Similarly, in Israel, with its intensive program of groundwater recycling for irrigation, increasing groundwater salinity has been reported due to the accumulation of soluble minerals rejected by the crops (71). The problem threatens the survival of economically vital citrus groves and avocado plantations.

Soviet scientists report that both the Caspian and Aral Seas are in retreat from irrigation schemes that tap excessive amounts of water from their watersheds. The Aral Sea, in particular, is shrinking dramatically in size—the water level has dropped 3 meters since 1960, reducing the sea's size by some 18,000 square kilometers (72). By the year 2000, if present trends continue and more land is irrigated, its level will drop 9–13 meters below its original level (73). The Caspian Sea is not only suffering from falling water levels due to irrigation and industrial uses, but it is filling up with silt as well. As a result, the catch of sturgeon—and consequently the production of caviar—has been reduced, cutting into an industry that provides needed foreign currency.

Massive amounts of salts have been monitored in the irrigated basins of the Aral Sea (74). Complete use of regional stable runoff for crop production may permit a

Figure 8.10 Declining Groundwater Levels and Related Problems in the United States


Area Problem
▭ Area in which significant groundwater overdraft is occurring
▭ Unshaded area may not be problem-free, but the problem was not considered major
Boundaries
Water resources region
Subregion
Specific Problems (as identified by U.S. Federal and State/Regional study teams)
● Declining groundwater levels
▲ Diminished springflow and streamflow
◆ Formation of fissures and subsidence
■ Saline water intrusion into freshwater aquifers

Source: V.J. Pye, *et al.*, *Groundwater Contamination in the United States* (University of Pennsylvania Press, Philadelphia, 1983) doubling of the present irrigated areas, and if the proposed water transfers from the Siberian rivers materialize, the irrigated areas around the Caspian and Aral Seas may expand sixfold. However, the reduced river flow to the Aral Sea has already increased its salinity threefold, to one gram per liter (75). By the year 2000, the salinity is expected to increase further, up to 3.5 grams per liter. The reduced flows to the Aral Sea may mean that the salts will have to accumulate elsewhere, and in the end, the second largest inland sea in the Soviet Union is expected to be converted into a small salty lake. The tragedy of the situation is underlined by estimates that suggest that the diversion of the Siberian rivers south into the Aral Sea Basin will still supply only about 25 percent of the estimated water deficiencies (76).

PRICING

The general misconception that freshwater is a free and endless resource has seriously delayed society's need to adapt to the limits of a fixed supply (77). Lack of appropriate pricing policies only encourages the inefficient and wasteful use of existing reserves. In developed countries, industrial water use is declining, in part because of better pricing systems as well as water quality concerns. Studies carried out in the United States in the early 1970s clearly demonstrated that the cost of water was a prime factor in its use. At a very low price for water (around one cent per 1000 gallons), a fossil fuel-fired, steam, electric generating plant would use as much as 50 gallons per kilowatt hour (kWh) of electricity generated. As the price increased to five cents per 1,000 gallons, the plant would switch to a cooling tower, reducing raw water demand to about 0.8 gallons per kWh—a decrease of almost two orders of magnitude. If the price of water were to go to $8 per 1,000 gallons in dry regions, then a dry cooling tower, with effectively zero water use, would be the most economical technology to employ (78). In other words, from the western U.S. experience, a fivefold increase in the price of water leads to a fiftyfold decrease in use (79).

The same is true for municipal water uses. In the United States, studies have shown that consumers use substantially less water in municipal systems that have meters and higher prices. It has been demonstrated that a 10 percent increase in the price of water will result in a 1.5–7 percent drop in water demand (80).

Additionally, there is a direct correlation between the cost of water and irrigation efficiency. The U.S. Bureau of Reclamation found that at a cost of $1–3 per acre-foot of water, irrigation efficiency was less than 40 percent, but as the cost of water increased to $10 per acre-foot, irrigation efficiency improved to over 60 percent (81).

EMERGING TRENDS IN WATER USE

As recently as the late 1960s, a few experts were projecting drastic increases in water use by the turn of the century—up to 15,000 cubic kilometers per year (82). Even if these estimates prove unrealistic, it is obvious that water demands are increasing. A number of experts conclude that as water demand increases, groundwater reserves will start to be mined at a greater rate. During the past 20 years, groundwater development has increased noticeably in Mexico, the United States, and Canada. Groundwater supplies more than 10 percent of Canada's drinking water, and in 1980, the United States withdrew 124 km^3 of groundwater for all purposes (83), up from 47 km^3 in 1950 (84). This trend is expected to continue into the next century.

As developing countries expand both agricultural and industrial activities over the next 20 years, there will be considerable pressure to increase pumping from underground reservoirs. And if their supplies consist mostly of fossil groundwater, then some water-short countries could end up mining a non-renewable resource; it takes thousands and sometimes millions of years to replenish fossil groundwater stocks.

WATER POLLUTION

Since the dawn of history, humankind has manipulated the freshwater system in order to augment dependable supplies by pumping, piping, channeling, damming, storing, draining, and tilling. In other words, human activities have proved to be an integral part of the water cycle (85).

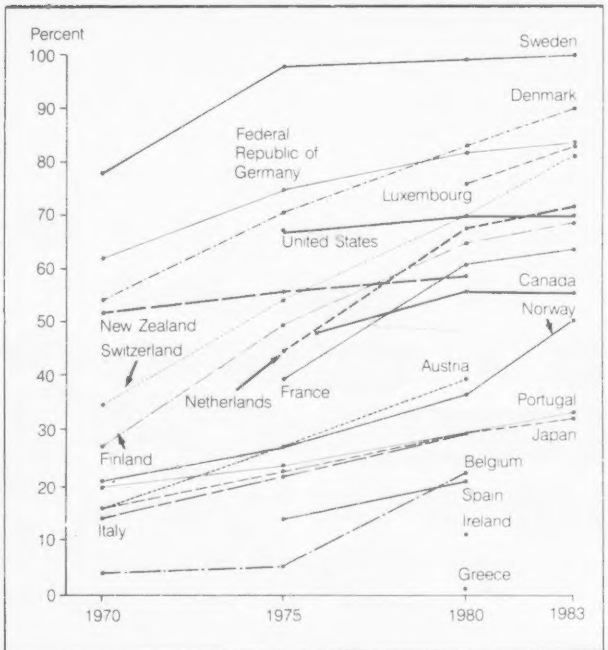
In Europe and the United States, where industrial development took place under relatively water-rich conditions, the wastes were returned to the rivers, generating adverse environmental effects. As water demands increased for municipalities, industry, hydropower, and waste treatment and as vast land reclamation projects were developed, the quality of the water in aquifers, rivers and streams, and lakes began to deteriorate.

The fouling of water courses and lakes by industrial processes and sewage treatment has been one of the hallmarks of this century, but the process has accelerated rapidly, especially since the Second World War. Consequently, water pollution issues have attracted active public interest in many regions of the world.

The basic type of water pollution, well known in both developed and developing countries, is the pollution caused by the discharge of untreated or inadequately treated waste water into rivers, lakes, and reservoirs. Over much of the industrialized world, waste water treatment plants employing various technologies have been installed at considerable costs to reduce the discharge of polluted effluents into freshwater systems. Figure 8.11 shows a consistent upward trend in the number of people served by waste water treatment plants in the Organization for Economic Co-operation and Development (OECD) countries, although there is considerable variation in the percentage of the population covered: from 20 percent for Spain and Belgium to nearly 100 percent in Sweden. In the developing world, however, the trends are just the opposite—as their rudimentary industrial bases take shape and populations expand, water pollution control and waste water and sewage treatment are either non-existent or are wholly unable to keep pace with levels of pollution (86).

As industrial waste water flows increase and become more complex, with higher loads of inorganic and toxic chemical compounds, new pollution problems develop.

Figure 8.11 Percentage of Population Served by Waste-Water Treatment Plants, 1970–83



Source: Organization for Economic Co-operation and Development (OECD), *State of the Environment 1985* (OECD, Paris, 1985).

Local fish-kills attributable to the effects of toxic substances in the water become commonplace. In order to minimize these pollution effects, most developed countries such as Sweden, as mentioned earlier, used legislation to force technical improvements in the way municipalities and industries treat and dispose of their waste products (87). On the other side of the ledger, developing countries like India, China, Indonesia, Tanzania, and Kenya are among those Third World nations suffering from an increase in industrial pollution of their freshwater systems.

Another water quality problem is the increasing eutrophication of rivers and lakes, despite municipal waste water treatment. This type of pollution, called nonpoint pollution, is caused mainly by the runoff of pesticides, herbicides, and fertilizers from agricultural lands (88). Since the 1950s, there has been a marked increase in the concentration of phosphate (phosphorous) and nitrates in the inland waters of many countries, particularly North America and Europe. This rise reflects the increased use of detergents and fertilizers. Two of the most notable cases of eutrophication involve Lake Balaton in Hungary and Lake Geneva (wedged between France and Switzerland). Both lakes suffer from an overdose of nutrients brought in by the chemical runoff from nearby agricultural lands, mainly vineyards and farmland. Eutrophication is also a major problem in reservoirs and artificial lakes used for community water supplies, particularly in Morocco and many countries in Latin America.

The overall quality of the water in rivers and streams of OECD countries—as measured by the amount of dissolved oxygen in a river or lake and the amount of biological oxygen demand (BOD) from the introduced waste—has improved since the 1970s (89). (See Table 8.8.) By and large there is more dissolved oxygen in the rivers of OECD countries than in the 1970s, pointing to the effects of clean water legislation, particularly the introduction of secondary (biological) and tertiary (chemical) treatment of waste water. This trend is further confirmed by national surveys, which show reductions in the discharge of oxygen-consuming substances and improvements in the water quality of many rivers in the United States, Japan, France, the Netherlands, the United Kingdom, and the Nordic countries (90). Nevertheless, stretches of some rivers in these same countries are still polluted.

The 42 rivers monitored in the OECD countries since 1970 have also shown a consistent improvement as regards certain other pollutants. The measurable amounts of ammonium have decreased along with those for heavy metals like lead and cadmium. In the Rhine River (at a site in West Germany), lead, in fact, has shown a dramatic decrease, from 24 micrograms per liter (μg/l) in 1975 to 8 μg/l in 1983 (91). Over the same period, cadmium in the Rhine (at the same site) declined from 2.40 μg/l in 1975, to only 0.40 μg/l in 1983 (92).

Similar data for developing countries are nearly nonexistent, but scattered reports and the few monitoring data available indicate that pollution is a growing problem. India is a classic example: 70 percent of its total surface waters are polluted (93). Out of India's 3,119 towns and cities, only 217 have partial (209) or full (8) sewage treatment facilities (94). The result is severely contaminated waters. A 48-kilometer stretch of the Yamuna River, which flows through New Dehli, contains 7,500 coliform organisms per 100 milliliters (ml) of water before entering the capital, but after receiving an estimated 200 million liters of untreated sewage every day, it leaves New Dehli carrying an incredible 24 million coliform organisms per 100 ml (95). Industry is no better. That same stretch of the Yamuna River picks up 20 million liters of industrial effluents, including about 500,000 liters of "DDT wastes" every day (96).

China's rivers also seem to be suffering from increasing pollution loads. Of the 78 monitored rivers in the People's Republic, 54 are reported to be seriously polluted with untreated sewage and industrial wastes. The Huangpujian River, a major source of drinking water for Shanghai, carries one volume of untreated wastes for each four to six volumes of water (97). Malaysian rivers, in turn, are becoming ecological disasters. Reports indicate that more than 40 major rivers are so polluted that they are nearly devoid of fish and aquatic mammals. The primary pollutants were identified as oil palm and rubber processing residues, sewage, and industrial wastes (98).

Rivers in the Soviet Union are becoming more polluted as industries expand. Industrial waste waters are said to comprise a full 10 percent of the Volga River's average flow at Volgograd, with three quarters of the wastes discharged into the river untreated (99).

Table 8.8 Water Quality Indicators for Selected Rivers, 1970–83

(milligrams per liter)

		Dissolved Oxygen (DO)[a]					Biological Oxygen Demand (BOD)[a]				
		1970	1975	1980	1983	Average Last 3 Years Avail.	1970	1975	1980	1983	Average Last 3 Years Avail.
Canada	St. Lawrence	8.1	10.0	X	X	X	X	X	X	X	X
United States	Delaware-Trenton	9.6	10.8	11.9	10.3	11.1	1.9	2.0	2.2	2.6	2.8
	Mississippi-St. Francis	8.4	3.5	8.3	8.9	8.9	2.4	2.2	1.7	1.1	1.8
Japan	Ishikari	8.7	10.7	10.6	10.6	10.5	1.7	1.4	1.4	1.5	1.4
	Yodo	8.3	8.9	9.0	8.2	8.0	3.6	3.2	3.8	4.2	4.1
Australia	Brisbane Estuary[b,c]	X	5.6	6.4	6.0	6.2	X	1.6	1.0	1.2	1.2
New Zealand	Waikato[d]	X	9.0	X	X	X	X	1.5	X	X	X
Belgium	Meuse-Heer/Agi[e]	8.2	10.8	10.6	X	10.7	4.4	6.6	4.2	X	4.7
	Meuse-Lanaye[f]	7.7	8.9	9.5	X	9.2	12.5	4.7	3.9	X	4.0
	Escaut-Bleharies	X	4.0	5.9	X	4.7	X	24.1	10.7	X	9.6
	Escaut-Doel[e]	6.2	1.3	1.9	X	2.1	4.0	8.2	5.0	X	14.0
Denmark	Gudenaa	X	X	9.7	10.7	10.2	X	X	3.4	4.5	4.3
	Skjernaa[g]	X	X	10.5	10.4	10.4	X	X	7.3	8.0	8.3
	Susaa	X	X	X	8.7	9.1	X	X	X	2.0	2.1
Finland	Tornionjoki	11.9	11.9	12.0	X	11.9	1.6	1.6	X	X	1.7
	Kymijoki	9.5	10.8	9.9	X	10.8	3.5	2.4	X	X	2.5
France	Loire-Nantes[e,h]	10.7	11.1	11.8	12.0	11.6	6.7	4.4	6.6	6.7	6.0
	Seine-Tancarville[e,h]	X	3.3	4.9	5.9	5.2	X	10.2	6.6	4.1	4.9
	Garonne-Bordeaux[e,h]	9.7	9.9	10.1	9.9	9.9	2.2	1.5	2.3	2.3	2.1
	Rhine-Selz[e]	8.2	9.2	10.9	8.6	8.9	X	4.1	4.8	3.0	3.6
Germany	Rhine-Bimmen L.	5.6	6.5	8.4	9.1	9.0	6.1	6.9	3.6	3.5	3.6
Italy	Po[i]	X	X	X	X	X	X	7.3	7.3	X	7.2
Netherlands	Meuse-Keizersveer	8.6	9.4	10.0	9.7	9.8	6.2	4.2	2.3	2.0	2.3
	Meuse-Eijsden	9.8	9.5	9.8	8.7	9.1	4.1	3.7	2.8	2.8	2.8
	Scheur-Maasluis	X	7.1	8.1	8.7	8.5	X	3.3	2.2	1.5	1.9
	Ijssel-Kampen	6.7	6.7	8.1	8.2	8.4	5.7	6.3	3.9	2.3	2.7
Norway	Skienselva	X	X	X	6.0	X	X	2.5	3.5	X	X
Portugal	Tejo	9.0	X	9.0	X	X	1.6	X	2.5	X	X
Spain	Guadalquivir[b,g]	X	X	X	X	X	X	12.3	11.8	X	8.2
Switzerland	Rhine-Village	11.6	11.2	10.3	10.2	10.4	X	X	X	X	X
	Aare-Brugg[b,g]	X	10.2	0.2	X	10.4	X	X	X	X	X
	Limmat-Baden[e]	X	X	9.1	X	X	X	X	X	X	X
	Rhone-Port du Scex[b,g]	X	10.7	10.9	X	11.0	X	X	X	X	X
United Kingdom	Thames	X	10.8	9.9	9.8	9.9	X	4.2	X	X	4.0
	Severn	X	10.5	10.3	11.5	10.7	X	3.9	X	X	3.2
	Clyde	X	7.7	9.4	8.4	8.5	X	7.3	5.6	X	5.3
	Mersey	X	5.1	6.1	6.1	6.1	X	8.6	X	X	X
Yugoslavia	Dunau	9.6	9.1	9.2	X	9.5	3.4	2.5	3.5	X	3.7
	Drava	8.8	7.4	10.1	X	10.0	3.4	2.6	3.1	X	3.1

X = not available

Notes:

a Measured at the mouth or downstream frontier of river

b 1975 data refer to 1976

c Data refer to fiscal year (i.e., 1983 refers to 1982–83)
Data for the same indicator may not be comparable because of measurements by different authorities. 1972–75 data are not comparable with those of later years because of different recording methods

d Data are approximate

e 1970 data refer to 1971

f 1970 data refer to 1972

g 1980 data refer to 1979

h 1983 data refer to 1982

i 1980 data refer to 1978

Source: Organization for Economic Co-operation and Development (OECD), 1985. Reference 89.

Polluted Groundwater

Nitrate concentrations in groundwater reserves have been increasing for the past decade, giving rise to health concerns (100). Today, elevated levels of nitrates in drinking water—from both natural and anthropogenic sources—are considered among the worst forms of groundwater pollution facing Europe and North America. With the increasing use of fertilizers in the Third World, similar problems are expected to crop up during the next decade in the South. According to a recent assessment, forests, dry steppes, and semi-arid areas under temperate conditions carry higher risks of nitrate leaching than similar areas in tropical climates, which should have fewer problems with nitrates in drinking water (101).

The disposal of human wastes from septic tanks and agricultural activities, including fertilizers and wastes from livestock, are the two largest sources of nitrate contamination of groundwater throughout the United States. (See Figure 8.12.) Recent surveys indicate that out of more than 124,000 wells sampled, 24,000 (20 percent) had water with maximum nitrate-nitrogen concentrations greater than 3 mg/l (102). Of these wells, some 8,200 had nitrate-nitrogen concentrations that exceeded the U.S. Environmental Protection Agency's regulatory limit of 10 mg/l. The U.S. Geological Survey notes that "in most instances, elevated nitrate concentrations occurred in water from wells in shallow aquifers, although long-term increases of nitrate in deep aquifers are possible where the aquifers are recharged by nitrate-rich water from shallow aquifers or from the land surface" (103).

The pollution threat in Europe and North America is also aggravated by the seepage of toxic chemicals from waste dumps that slowly percolate into the groundwater table. In the United States, some 10–20 percent of the 10,000 identified dump sites for hazardous wastes are considered a potential threat to groundwater reserves (104). City dumps (called "sanitary landfills") containing household garbage and solid wastes also produce leachate that can infiltrate groundwater systems.

China reports that 41 out of 44 large cities suffer from polluted groundwater. This pollution is thought to be responsible for the high levels of heavy metals monitored in urban and suburban vegetable gardens (105).

Similarly, European countries are suffering from increased levels of toxic substances seeping into groundwater reservoirs (106).

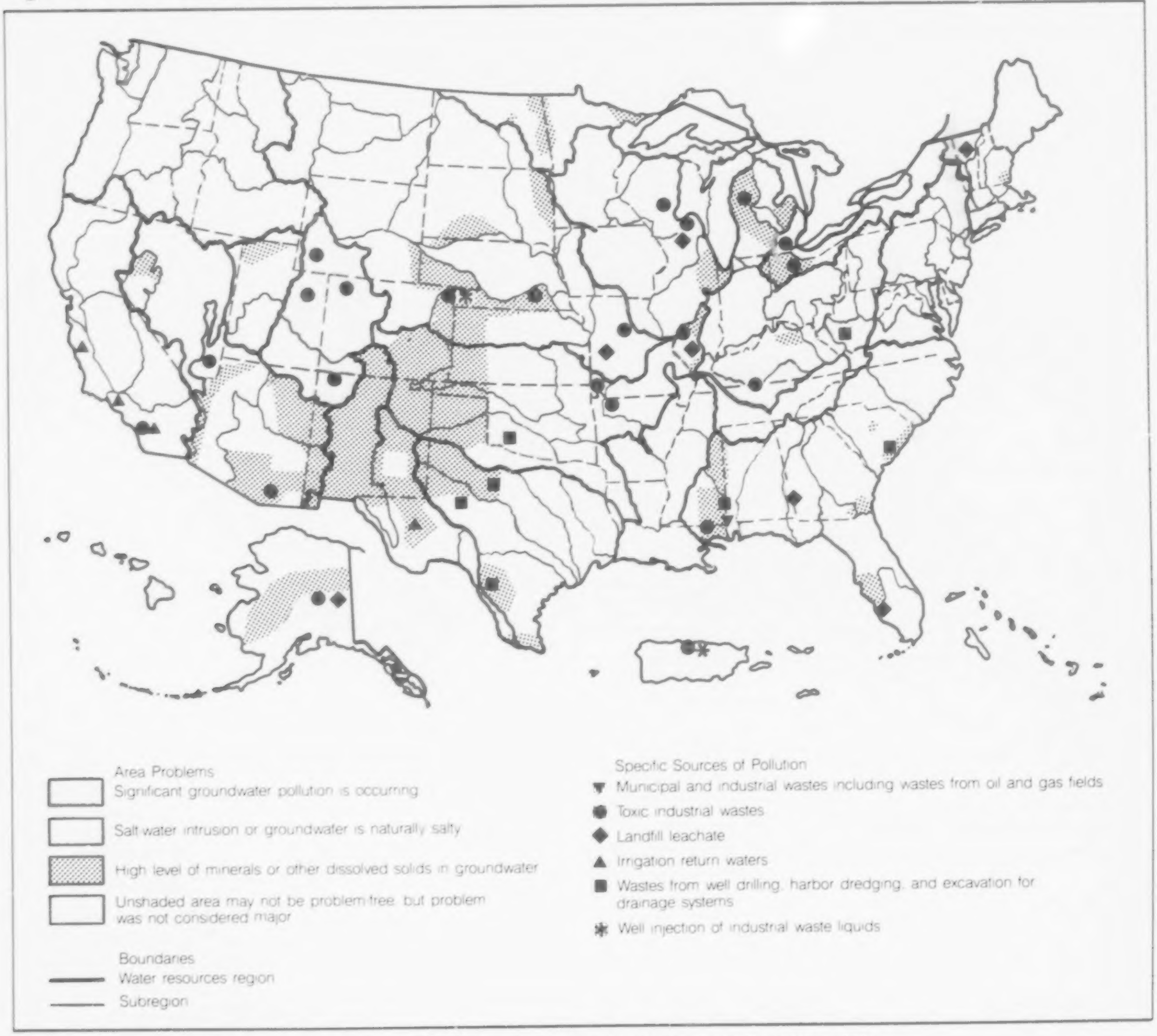
In order to prevent groundwater contamination in the future, policymakers must clearly grasp the processes involved. Groundwater pollution, which is the result of a long-term process, must be detected at an early stage. Because of the very slow rate at which groundwater moves, once groundwater is polluted and unfit for consumption, it might take decades, centuries, or even millenia before natural processes flush out the pollution (107).

A LOOK AHEAD

Managing water demand instead of increasing supplies will become extremely important over the course of the next two decades. Water-efficient technologies in agriculture and industry must be developed and widely used if humankind is to avoid a worsening water crisis in the coming decades, especially in water-poor regions.

Irrigation efficiencies, which now stand at a world average of only 37 percent (mostly due to overirrigation and to transport losses), must be increased. Obviously, there is much scope for improvement. Better management of canal systems alone will reduce water losses from irrigation in the Third World by 10–15 percent.

Figure 8.12 Groundwater Pollution in the United States


Area Problems
Significant groundwater pollution is occurring
Salt water intrusion or groundwater is naturally salty
High level of minerals or other dissolved solids in groundwater
Unshaded area may not be problem-free, but problem was not considered major
Boundaries
Water resources region
Subregion
Specific Sources of Pollution
Municipal and industrial wastes including wastes from oil and gas fields
Toxic industrial wastes
Landfill leachate
Irrigation return waters
Wastes from well drilling, harbor dredging, and excavation for drainage systems
Well injection of industrial waste liquids

Source: V.J. Pye *et al.*, *Groundwater Contamination in the United States* (University of Pennsylvania Press, Philadelphia, 1983).

In order to accomplish better management of water resources, water pricing may emerge as one of the best tools, along with further government regulation and education.

RECENT DEVELOPMENTS

INTERNATIONAL DRINKING WATER AND SANITATION DECADE

The International Drinking Water and Sanitation Decade (1981–90), launched by the United Nations in 1980, is creating a global awareness among policymakers of the importance of potable water in the fight against disease by promoting and strengthening public sector institutions in managing water resources (108). But translating the ambitious goal of bringing freshwater and proper sanitation to all by the year 1990 would necessitate the provision of water supplies for 500,000 people every day during the entire decade (109). To achieve this goal in a mere 10 years is proving unrealistic.

Still, it is an urgent need for public health reasons, as well as to end malnutrition. Infections from unclean water can cause malnutrition despite an adequate calorie supply. Coordinated education in sanitation, nutrition, and health is essential (110).

THE INTERDEPENDENCE OF LAND AND WATER

At a recent seminar on "River Basin Strategy," sponsored by the International Water Resources Association (IWRA), water experts from semi-arid zones called for an integrated approach to water management to meet the dual problems of soil and water degradation from land-based activities. It is apparent that the "water illiteracy" prevalent among planners needs to be overcome if new strategies are to be implemented to deal with the narrowing gap between supplies and consumption in water-scarce regions (111).

From a policy perspective, attention is also being focused on the whole field of watershed management. International assistance is stressing the importance of land conservation as a measure of disaster prevention, bringing water conservation as one of its main benefits. An international conference held in Ibadan, Nigeria, in 1979 on "Tropical Agricultural Hydrology" drew attention to the technical solutions being tried successfully in various tropical environments. Problems remain unresolved in areas with heavily populated watersheds subjected to widespread subsistence farming and livestock raising (112).

A recent meeting in Lidingö, Sweden—"Innovation for Development"—was sponsored by the International Inventors Awards. Experts concluded that any innovations in the area of water management should address not only the existing constraints imposed by the hydrological cycle itself but those induced by steadily increasing water demands for industry and agriculture, by ongoing land degradation in catchment areas, and by worldwide water quality deterioration (113).

MULTINATIONAL USE OF SHARED WATER RESOURCES

By the mid-1970s, around 40 percent of the world population was estimated to live in international river basins, that is, in countries dependent on imported (exogenous) water (114). The amount and quality of most of this water are controlled by activities in upstream countries: the larger the irrigation schemes in upstream countries, the less water there is for downstream uses; the larger the polluting activities in upstream countries, the poorer is the quality of water arriving in downstream countries.

The degree to which continental rivers are international in character varies considerably in response to geography, size of the countries, etc. (115). (See Table 8.9.) In Africa, for example, most of the river systems spill across national boundaries. This situation makes the African continent particularly sensitive to the problems of shared water resources. In several cases countries have mutual interests in increasing the dependable flow of water. Both Egypt and the Sudan, for example, have a vital stake in water storage and flow control schemes on the Nile (116).

The Rhine River, on the other hand, is a classic example of conflicting water quality interests. Both France and the Federal Republic of Germany use Rhine water for industrial purposes, discharging heavy pollution loads that the Dutch must clean downstream for drinking water. In India, the Ganges River is an example of where an upstream country diverts great quantities of river water for its own use (mainly for flushing out Calcutta harbor), thereby reducing the stable river flow for the downstream country of Bangladesh (117).

At the United Nations Water Conference in Mar del Plata, Argentina in 1977, considerable interest was given to the issue of international river basins and the need for river basin authorities (118). Many downstream countries joined together in calling for an "international code of conduct" that would attempt to set guidelines or limits on how upstream and downstream countries could use their shared resource. There is clearly a need to strengthen the force of international law as an instrument to induce states into cooperative measures to safeguard common water resources. An "international code of conduct" would encourage countries to cooperate on more specific water use and water quality issues.

The United Nations Water Conference provided a number of countries—particularly Argentina, Egypt, Mexico, and Romania—with the impetus needed to formulate and

Table 8.9 International Rivers By Continent

Continent	Population 1973 (millions)	International River Basins	River Basins Shared by Four or More Countries	Number of Treaties 1972
Africa	270	56	12	34
North and Central America	90	34		38
South America	100	36	2	31
Asia	600[a]	40	5	31
Europe	330	48	4	175
Total	**1390[a]**	**214**	**23**	**309**

Note: a. Data are approximate.
Source: Widstrand, 1980, Reference 114.

implement long-range planning based on "demand projections, comprehensive river basin planning and water economy budgets" (119).

Over the decade from 1975 to 1985, there was a discernible trend toward the establishment of river basin authorities such as the ones in the Sokoto River Basin in Nigeria and the Volta Basin in Burkina Faso (120). Developed countries also expanded their management capacities. In the United Kingdom, for example, the government established a network of regional water authorities responsible for supply, conservation, and waste water treatment (121).

WATER LAW

Water law also gained importance in both developed and developing countries over the same period. At least one third of all countries in the world revised their administrative and statutory arrangements for regulating water resources. These embraced water rights, water and land control, pollution, and waste water treatment (122).

From 1972 to 1982, the international community enlarged its research and educational capabilities. Three efforts stand out: the creation of the Water Research Centre in the United Kingdom; the establishment of the Institute of Water Economics, Legislation and Administration in Latin America; and the founding of the International Training Center for Water Resources Management in France (123).

Since the founding of the United Nations Environment Program in 1972, major new water pollution control statutes were enacted in the United States, New Zealand, the Federal Republic of Germany, Greece, Ireland, Italy, the Netherlands, Spain, the United Kingdom, and the Soviet Union (124).

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9. Oceans and Coasts

Oceans cover more than two thirds of the earth's surface and sustain numerous valuable living resources. Over half the population in the developing countries obtains 40 percent or more of its total animal protein supplies from fish (1). Fish products are also used for animal feed, for fertilizer, and in soaps, pharmaceuticals, and other commercial products.

CONDITIONS AND TRENDS

Nearly all the world catch of marine species is taken within 320 kilometers of land, the zone where more than half the total biological productivity of the oceans occurs (2). Unfortunately, coastal areas are also subject to a variety of human pressures that could severely degrade the natural resource base.

WORLD FISHERIES

The Marine Fisheries Harvest

The total world fisheries catch has increased during the past few decades. Between 1950 and 1970, it rose steadily and rapidly at an annual rate of about 7 percent. (See Table 9.1.) Then between 1971 and 1972 the total catch dropped, largely due to the dramatic fall in the catches of Peruvian anchovy which was then by far the largest fishery in the world. Since 1972 the catch has been increasing again, but only at 1–2 percent annually. The present marine catch totals some 76 million metric tons annually.

Fisheries in the North Pacific and North Atlantic dominate the world's fish harvest, accounting for more than half the total catch. Formerly the home of the world's major fishing fleets, these areas continue to dominate because they are exceptionally well-endowed with the shallow continental shelves on which most commercial species are found.

The steady rise of the world total catch is not typical of the catch from individual fisheries, which may fluxuate. The typical history of exploitation of an individual stock is for catches to remain at a low level (or even zero) until the stock is located by a long-range fleet, or a technical or marketing development triggers the growth of a local fishery. Growth can then be very fast, doubling each year for a decade or more (as occurred with the Peruvian anchoveta). But this situation is exceptional; growth rates of 20 percent or even 50 percent per year are more common.

If the resource is fairly resilient under heavy exploitation, catches may reach an asymptote equal to the productive capacity of the resource. But less stable stocks may collapse under too-heavy fishing, and the catches may drop to a low level or even zero. Between 1960 and 1983, tuna and Alaskan pollack catches substantially increased. Peruvian anchovy catches, however, declined dramatically during this period as fishing pressures became excessive. (See Table 9.2.)

Table 9.1 Nominal Annual Fisheries Catches, 1950–83

(millions of metric tons)

	1950–54[a]	1955–59	1960–64	1965–69	1970–74	1975–79	1980	1981	1982	1983
North Atlantic	9.2	10.2	11.2	14.3	15.3	15.5	14.0	14.5	13.6	13.8
Central Atlantic	2.0	2.3	3.1	3.9	5.9	6.4	6.9	6.8	7.2	7.3
South Atlantic	0.9	1.2	1.9	3.5	3.7	3.9	3.4	3.6	3.9	4.0
North Pacific[b]	2.8	3.5	4.7	13.2	17.9	20.0	20.7	21.9	22.6	23.6
Central Pacific[b]	5.1	7.7	10.2	4.0	6.1	7.1	7.9	8.5	8.2	7.8
South Pacific	0.3	1.2	7.2	13.3	8.2	5.7	6.6	7.2	8.3	6.6
Indian Ocean	1.2	1.4	1.7	2.6	2.8	3.3	3.6	3.6	3.7	4.0
Antarctic	NA	NA	NA	NA	0.1	0.3	0.6	6.0	0.7	0.4
Total Marine	21.6	27.7	40.0	51.6	60.0	63.7	64.4	66.7	68.0	67.7
Inland	3.1	4.5	6.2	7.9	7.9	7.4	7.6	8.2	8.4	8.9
World Total	**24.7**	**32.2**	**46.2**	**59.5**	**67.9**	**72.1**	**72.0**	**74.9**	**76.4**	**76.6**

NA = not applicable

Notes:

a. Data for 1950-79 are five-year averages.

b. The division between Central Pacific and North Pacific was shifted northward after 1965.

Source: U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics: Catches and Landings*, for relevant years.

FISH CONSUMPTION AND TRADE

Compared with the gross production from agriculture, the contribution of marine fish to human intake of animal protein is quite small. However, as noted earlier, it can be very important locally, particularly for people in coastal developing countries. People in some developed countries, such as Japan and Iceland, also rely on fish for an important part of their daily diet.

Not all the marine fish catch goes directly onto the table. A significant proportion of the low-valued species (anchovy, sand eels, etc.), as well as the waste from processing the higher-valued species, is turned into fish meal. This is then fed to poultry or other farm animals and appears in the human dish secondhand.

Fish is an increasingly important source of foreign exchange earnings. World exports of the major fishery commodities now exceed $15 billion annually. Prices for fish and fish products range from $100 per metric ton to more than $5,000 per metric ton. Although the data are limited, it appears that in most countries fish prices have risen more rapidly than the prices of other foods (3).

The rise in prices partially reflects changes in fish packaging. During the 1950s, about half the world catch was consumed fresh and only 1 percent was frozen (4). Today, frozen fish for human consumption comprises 22 percent of the total catch, but the amount marketed fresh has fallen to 20 percent. The share of canned fish has increased from 6 percent in the 1950s to 13 percent in 1982. Cured fish (sundried, salted, pickled, or smoked) has dropped from 33 percent of the world catch in 1951 to just 14 percent in 1982 (5). The rest of the catch, some 31 percent, is used for other purposes such as fish meal for poultry or for manufacturing soap, pharmaceuticals, etc.

Fish prices and trade are also influenced by consumption patterns. Fish use for human consumption and industrial purposes grew rapidly from 1960 to 1970. After 1970, human consumption continued to grow, and the production of fish meal declined slightly from its 1970 peak (6). Most of the growth in human consumption occurred in developing nations.

An analysis of catches by economic groupings reveals that while developed countries still harvest more than half the world catch, there has been a steady upward trend in the harvests of developing countries, especially those in Asia. Developing countries collectively increased their annual fish harvests by 3.5 percent from 1977–81 while developed countries' harvests grew a modest 0.7 percent. Five of the top ten fish-producing nations in 1982 were developing countries. (See Table 9.3.)

Developed countries dominate international trade in fish and fish products, but developing countries are taking a larger share of this trade. Between 1974 and 1982, the volume of exports of fish and fish products from developing countries doubled, and their value tripled. The Republic of Korea, Mexico, Thailand, India, Chile, and Argentina are among the countries with the most significant increases in fish exports (7). (See Table 9.4 for data

Table 9.2 Catches of Selected Species and Species Groups, 1960–83

(millions of metric tons)

	1960–64	1965–69	1970–74	1975–79	1980	1981	1982	1983
Salmon, Trout, Smelts, etc.	0.4	0.4	0.4	0.5	0.6	0.7	0.6	0.7
Tunas, Bonitos, Billfishes, etc.	1.1	1.3	1.7	1.8	2.6	2.6	2.7	2.8
Mackerels, Snoeks, Cutlassfishes, etc. (*Scomber* spp)	1.7	1.9	2.6	3.6	3.3	3.1	2.5	2.2
Jacks, Mullets, Sauries, etc. (Trachurus)	1.1	1.0	1.6	2.4	2.8	3.2	3.9	3.2
Atlantic Herring	2.8	3.5	2.0	1.1	0.9	1.0	1.0	1.1
Sardines (Sardinops & Sardina)	1.5	1.9	1.4	4.4	7.1	7.9	8.6	9.5
Anchoveta (Peru only)	6.6	9.8	9.0	2.2	0.8	1.6	1.8	0.1
Atlantic Cod	2.4	3.2	2.8	2.3	2.2	2.3	2.3	2.1
Alaskan Pollack	0.6	1.9	3.1	4.4	4.0	4.2	4.5	5.0
Total Marine Finfish	**34.5**	**47.2**	**52.5**	**56.0**	**56.2**	**58.4**	**59.2**	**58.8**
Shrimp, Prawns, etc.	0.6	0.8	1.1	1.4	1.7	1.6	1.7	1.8
Squid, Cuttlefishes, Octopuses, etc.	0.8	1.0	1.0	1.3	1.5	1.4	1.6	1.6

Note: Data for 1950-79 are five-year averages.

Source: U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics*, for relevant years.

Table 9.3 Ten Countries with Largest Fish Production, 1982

Country	1978	1979	1980	1981	1982	1981–82 % change
	(thousands of metric tons)					
Japan	10,184	9,945	10,426	10,657	10,760	1.0
USSR	8,915	9,050	9,476	9,546	9,450	-1.0
United States	3,418	3,511	3,635	3,767	3,922	4.1
Chile	1,929	2,632	2,815	3,393	3,673	8.3
Peru	3,473	3,715	2,735	2,740	3,452	26.0
Norway	2,593	2,658	2,409	2,539	2,463	-3.0
India	2,306	2,340	2,438	2,415	2,400	-0.6
Korea, Republic of	2,092	2,162	2,091	2,366	2,281	-3.6
Indonesia	1,642	1,742	1,842	1,903	2,020	6.1
Denmark	1,740	1,738	2,026	1,852	1,907	3.0

Source: U.N. Food and Agriculture Organization (FAO), *INFOFISH Marketing Digest*, No. 5 (FAO, Rome, 1983), p. 1.

on the ten largest fish exporting and importing countries from 1974–82.)

FOCUS ON: THE IMPACTS OF THE NEW LAW OF THE SEA ON FISHERIES

By the end of 1985, 159 countries had signed the 1982 United Nations Convention on the Law of the Sea. Although the United States and several other major countries have not signed the treaty, the concept of a 200-mile Exclusive Economic Zone (EEZ) is already effectively in operation. This legal concept is a particularly significant one for fisheries, since it recognizes that coastal states have sovereign rights over all fishing (including that by foreign vessels) within 200 miles of their coasts. Foreign ships may be allowed access to fish in this zone when the potential harvest is greater than the amount harvested by the coastal nation. The definition of potential harvest is sufficiently vague, however, that coastal states can reasonably claim this quantity as the sum of their own catches plus the amount allowed to foreigners. (See Part IV, Chapter 10, "Oceans and Coasts.")

Many people expected that the 1982 Law of the Sea Convention would result in major changes in world fisheries. Some thought it would allow developing countries to take a larger share of the world catch—at the expense of fleets from rich, developed countries. Others feared that the total amount of fish caught might drop significantly because coastal states would not have the immediate capacity to replace foreign fishing vessels.

Neither expectation has been fulfilled. Since the bulk of distant water fishing was off the coasts of the developed world, these countries gained most in terms of control over fishery resources. The United States and Canada were the biggest gainers; others included Australia, New Zealand, South Africa, and many countries of northwestern Europe (8). Nevertheless, some developing countries, particularly the South Pacific island nations and some west African countries have also acquired legal control over valuable fisheries through the EEZ concept. Nor did the new legal regime lead to large short-term declines in total catch, because the developing coastal countries have allowed foreign fishing to continue, albeit under conditions that provide some benefits to the coastal country. These controls may determine the amount that can be caught, license fees, and the proportion of the catch that must be landed for local processing.

The catch trends in the years after the changes in jurisdiction have deviated from the predictions in different ways. In the Southeast Atlantic the share of non-local vessels remains high. Coastal states in this region have not benefited much because they lack enforcement capability. Most of the region's non-local catch is taken off the coast of Namibia, which suffers from both a lack of enforcement capacity and a government that is not generally recognized. Since the collapse in 1974 of the pilchard stock, which had been one of the mainstays of the local fishery, the share of non-local fishing has actually increased.

In the Northwest Atlantic fishing region, the long-range and total catches dropped substantially (9). This drop, however, was primarily due to overfishing that occurred prior to enactment of the new Exclusive Economic Zone provision rather than to the provision itself (10). The United States and Canada prohibited most foreign fishing in the area, which reduced fishing pressure on some of the more heavily-fished stocks. Domestic fishing still exerts moderate to heavy pressure, however, making recovery a slow process (11).

In two other areas, the Eastern Central Atlantic (off northwest Africa) and the Northeast Pacific (the Bering Sea and the Gulf of Alaska), the coastal countries have allowed foreign fishing to continue. The countries of northwest Africa do not currently have the capacity to replace a large reduction in foreign fishing. Generally speaking, there has been no need to reduce fishing to conserve stock. Overall, therefore, the total catch in these

Table 9.4 Ten Largest Exporters and Importers of Fish, 1982

Exporters	1981	1982	1981–82 Percent Change	Importers	1981	1982	1981–82 Percent Change
	(millions of dollars)				(millions of dollars)		
1. Canada	1,267	1,291	+ 2	1. Japan	3,737	3,998	+ 7
2. United States	1,142	1,034	- 9	2. United States	2,988	3,226	+ 8
3. Denmark	940	901	- 4	3. France	1,051	1,056	NC
4. Norway	1,002	888	-11	4. United Kingdom	995	886	-11
5. Japan	863	807	- 7	5. Germany, Federal Republic of	819	819	NC
6. Korea, Republic of	835	759	-11	6. Italy	720	755	+ 5
7. Mexico	538	620	+15	7. Spain	479	466	- 3
8. Iceland	713	536	-25	8. Hong Kong	362	467	+29
9. Netherlands	512	504	- 2	9. Nigeria	520	400	-23
10. Chile	365	408	+12	10. Belgium	348	327	- 6
Total	**8,177**	**7,748**	**- 5**	**Total**	**12,019**	**12,400**	**+ 3**
Percent of World Total	**53**	**50**		**Percent of World Total**	**74**	**75**	

NC = no change
Source: U.N. Food and Agriculture Organization (FAO), *Fishery Commodity Situation and Outlook* (FAO, Rome, 1983), p. 12.

Box 9.1 Regional Fish Harvest Trends

Fluctuations in regional catches have been much greater than changes in the total world catch. In some areas, such as the Western Central Atlantic, fish stocks that had been largely ignored or only lightly fished are being increasingly exploited. In others, such as the upwelling areas off Peru and off Southwest Africa, there have been major changes in the distribution and abundance of the fish stocks themselves.

The West Central Atlantic borders on North, Central, and South America. Catches in this region have been increasing annually since 1973 primarily because of increased fishing by Mexico (1). The United States, Cuba, Venezuela, and Brazil also exploit this region's resources extensively. The most important commercial fisheries are those for shrimp; these stocks are fully exploited and have changed little in the past decade. In terms of weight, however, the fish—especially pelagic fish such as menhaden—are more important. These stocks have been fished less heavily, and catches of some species are increasing significantly.

There has also been a large increase in the reported catches of anchovy in the Black Sea—though some of this may be due to improved statistical reporting, rather than bigger catches. In addition, the catches from the Mediterranean—where most stocks, especially around the European coasts, are fully exploited—have increased by 50 percent in the past decade.

The Southwest Atlantic offers the greatest opportunity for expanded fishery operations. Total catches in this region increased from 1.3 million metric tons in 1981 to 1.7 million metric tons in 1983. Larger catches of southern blue whiting and squid are primarily responsible for the increase (2). In this area, Polish fleets catch most of the southern blue whiting—a species that was virtually unexploited a few years ago. There is serious concern, however, that the stock will soon be overfished if the current rate of growth in the harvest continues. Polish, Japanese, Soviet, and Argentinian fleets catch the majority of squid in the Southwest Atlantic region. Squid harvests amounted to 200,000 metric tons in 1983 (3).

The abundance of red shrimp in the Southwest Atlantic has captured the interest of the world's fishing fleets. As a result, catches of red shrimp have been rising steadily: from 2,600 metric tons in 1981 to 19,000 metric tons in 1983 (4).

The biggest fishery in the Southwest Atlantic is still hake, exploited almost entirely by Argentinian and Uruguayan fleets. Catches of hake have been stable since 1980, and the species seems to be moderately exploited (5).

Changes in global meteorological conditions have a marked effect on the strength and direction of ocean currents, which in turn affect the distribution and migration patterns of fish. The unusual meteorologial conditions that arose in 1983 over the Pacific generated El Niño, a strong warm current off the west coast of South America that can extend across the Pacific as far as Indonesia. During that year the surface waters were unusually warm and this is thought to be the main cause of the dramatic reduction in the total catch from the South Pacific. Fisheries off the coast of Ecuador were most seriously affected; the mackerel migrated south, away from Ecuadorian fishing grounds and catches fell precipitously, from 700,000 metric tons in 1981 to 134,000 metric tons in 1983 (6).

Similar reductions have occurred in the Southeast Atlantic. Pilchard stocks off both South Africa and Namibia have been severely reduced by heavy local fishing. While there has been an increase in the abundance of horse mackerel, fished mainly by the long-range fleets from Eastern Europe, it has not been sufficient to prevent a decline in the area's total catch since the early 1970s. All the major stocks in the region—hake, horse mackerel, and anchovy—are now heavily fished. Unless the pilchard stocks recover, which they show no signs of doing, total catches from this region are unlikely to increase.

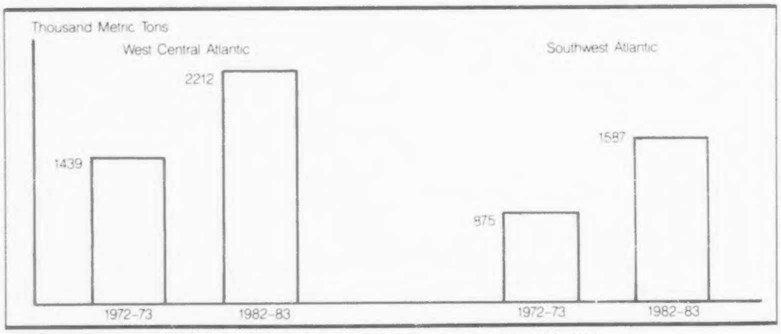
The most striking increase in a fishery catch has been that of the Japanese sardine, whose catches topped 4 million tons in 1983, compared with only 9,000 tons in 1965. This species has been the main contributor to the continued rise in catch totals from this region, currently some 21 million tons. Other important species in this region are Alaskan pollack, mackerel, squid, and a variety of demersal fish. Most of these and other species are heavily fished, though the potential exists for some increase in the production of squid from the off-shore regions.

On both sides of the Pacific the recent trends in salmon catches have been encouraging. All species of salmon had been severely reduced by heavy fishing, combined with the effects of pollution and environmental degradation in their spawning streams. Recent controls on the amount of fishing, both in the open ocean and in home waters, along with some improvements in river conditions and active re-stocking programs, have led to an upward trend in total catches.

References and Notes

1. U.N. Food and Agriculture Organization (FAO), *Review of the State of World Fishery Resources* (FAO, Fish Circular 710, Revision 4, 1985), p. 10.
2. *Ibid.*, p. 14.
3. *Op. cit.* 1, p. 15.
4. *Op. cit.* 1, p. 14.
5. *Op. cit.* 1, p. 16.
6. *Op. cit.* 1, p. 27.

Figure 1 Annual Fish Catch in Two Fishery Regions, 1972–83



Source: U.N. Food and Agriculture Organization. See Part IV "Oceans and Coasts," Table 10.2.

areas has remained unchanged. Domestic fishing has slowly increased, however, while foreign fishing has fallen slightly (12,13).

Similar patterns are apparent in most other areas—for example, around Australia and New Zealand, and off Argentina—where long-range fishing was significant. Where local capacity can replace foreign ships, it has largely done so, but elsewhere much foreign fishing remains (14).

Only a few developing countries have realized significant immediate gains from the changes in international ocean law. Many of these gains have come from economic cooperation with countries operating long-distance fleets. Cooperation often takes the form of joint ventures; the foreign nation usually provides the vessels, capital, technical know-how, and in some cases the markets, while the coastal country supplies access to the resource and the less skilled labor. Often arrangements are made so that as local people gain experience on foreign fleets, they assume more senior positions. Eventually the fishery becomes a coastal country's operation, supplying foreign markets.

Although the new legal regime may appear not to have made a significant impact on fisheries, it may yet play a key role in the management of the ocean's resources. Before the new law, the bulk of the marine fish catch was taken beyond recognized national jurisdiction, which varied from 3 to 12 miles. Management measures could be introduced only through international agreements entered into voluntarily by the countries concerned, and these measures were largely ineffective because they were based on the lowest common denominator. About 99 percent of the world catch is now taken in water that is already, or potentially, under the jurisdiction of a coastal country (15). The road to better management, therefore, is now open.

Marine Fisheries Potential

Various estimates have been made of how much fish can be taken from the sea. Estimates sometimes differ markedly, often because of differences in definitions—for example, technical potential versus economic potential, or conventional resource potential versus a combination of conventional and unconventional resource potential.

The most generally accepted estimates of *conventional resource potential* are on the order of 100 million metric tons (16). This figure includes the types of fish sold in fish markets or used for fish meal plus all other species of roughly similar characteristics. It is highly unlikely that the actual catches will ever approach this potential figure. Some stocks, for example the demersal fish in the deeper parts of the continental shelf in many tropical areas, though marketable, are scattered. With present technology, it is unlikely that sufficient quantities can be caught at a cost that is economically worthwhile. There are still some opportunities for increased catches (e.g., the demersal stocks off the northwest coast of Australia), but they are becoming increasingly limited.

Moreover, this estimate of potential assumes that each stock is exploited at its optimum level. Where several species live together and are vulnerable to the same fishing operations, it is not possible to fish each stock optimally; some are bound to be underexploited and others overexploited.

In practice, matters are often worse. Though fish stocks have proved remarkably robust in the face of uncontrolled exploitation, several have collapsed. Rebuilding these stocks (e.g., the Peruvian anchovy and the pilchard off Namibia), as well as maintaining the productivity of the stocks that provide a yield near the optimum, are essential if the world catch is to increase significantly, and to approach even 80–90 million metric tons.

Estimates of potential yield are higher if *unconventional resources* are also included. It is more difficult to give precise figures for economically feasible potential, however, because the quantity to be harvested depends on changes in consumer tastes and because the economics of harvesting these resources may change with improved technology. The best known unconventional resources are the krill in the Antarctic, several species of oceanic squid, and the lantern fish and other small fish in the upper parts of the deep oceans. Krill has attracted the most attention.

Krill certainly exist in large numbers. Estimates of theoretical potential yield vary greatly, but even the most conservative figures run into tens of millions of metric tons. Krill can be caught in large quantities—several tons per hour with a midwater trawl—but despite the region's low temperatures, their quality deteriorates rapidly, and processing must be rapid. This factor, combined with the bad weather of the Southern Ocean and the long distances from any base, makes a large proportion of the resource economically unattractive at present.

The total krill catch, taken mostly by the Soviet Union and Japan, increased rapidly between 1974 and 1980, reaching nearly half a million metric tons in the 1979–80 and 1980–81 seasons, and topping that figure in 1981–82. The catch then fell to some 220,000 metric tons in 1982–83, largely because of reduced fishing by the Soviet Union (17). The demand for krill in Japan is currently quite small—a few tens of thousands of metric tons. The falling Soviet catch suggests problems in disposing of the larger quantities. Thus, significant increases in the krill catch seem unlikely unless there is a major processing or marketing breakthrough.

The situation for the other unconventional resources is similar. The resources exist: for example, good catches have been taken by research vessels in the Arabian Sea, which seems particularly rich in meso-pelagic fish. The cost of fishing, however, still exceeds the likely return on any market (e.g., for fish meal) that would seem capable of absorbing large quantities. Really large-scale exploitation of meso-pelagic fish or oceanic squid seems at least as far off as a krill fishery.

Aquaculture is sometimes seen as a means of vastly increasing the total marine fish yield worldwide because it can produce much higher yields per unit of area than fishing can. A major constraint on total aquaculture production, however, is that most of the products that people want are high on the food chain, and therefore, are expensive to produce. Also, marine fish move over large areas, making it difficult to rear them in enclosures.

Mollusks are immobile after the first few days or weeks of life and in that sense are easy to culture, provided they grow large enough to be commercially attractive. Notable centers of mollusk culture are or have been western Europe (Holland and Spain for mussels, France for oysters), the United States (Chesapeake Bay for oysters), and Japan. Overall mollusks are a strong branch of aquaculture.

Shrimp, milkfish, and a few other species are also well suited to aquaculture. They are low enough on the food chain to provide reasonable yields per unit area; yet they are valuable enough to make the operation worthwhile. Where conditions are favorable (for example, Ecuador and Southeast Asia), shrimp culture in lagoons and similar areas is currently among the fastest growing fishery businesses. However, it has also been one of the major causes of mangrove degradation in these areas. (See "Mangroves," below.)

Aquaculture does offer further opportunities for increasing the marine fisheries harvest, but it will be restricted to very small areas.

FUTURE PROSPECTS

The outlook for marine fisheries is not bright. The factors that have caused recent problems—limited resources and excessive exploitation of these resources—are likely to continue. Although an increase in total catch can be expected from those stocks of conventional fish that are not fully exploited, the economic obstacles to large scale harvesting of krill and meso-pelagic fish are likely to remain for the immediate future. Some depleted stocks, especially herring off Norway and in the North Sea, are recovering, but neither the scientific knowledge nor the political will to prevent the collapse of similar stocks is certain. Fisheries that may be at risk include the sardines off northwest Africa (whose geographical range seems to have shrunk recently) and the oil-sardines off the west coast of India (which have periodically been scarce) (18).

By acquiring jurisdiction over the resources in a wide zone off their coasts, coastal nations have an opportunity to improve management by matching productivity of the resources with the fishing capacity used in harvesting them. Some countries have grasped this opportunity, and a few—like the United States, with its Fishery Conservation and Management Act of 1976—have combined extension of jurisdiction with a fundamental reexamination of how the resources in the new Exclusive Economic Zone should be conserved and utilized.

But overall, the problems have not been recognized. As long as a world fishery conference at the highest policymaking level has as one of its major recommendations a call for more investment in fisheries without strict reservations on how and where that investment is applied, the problem will remain. (See "Recent Developments," below.) Overcapacity will remain a threat to many resources, especially those such as herring and sardines, which seem particularly susceptible to overfishing. It will also be a major cause of conflict and reduced prosperity among fishermen, especially the small-scale fishermen of developing countries.

COASTAL ECOSYSTEMS

The coastal zone represents the transition from terrestrial to marine influences and vice versa. It comprises not only shoreline ecosystems but also the upland watersheds draining into coastal waters, and the nearshore sub-littoral ecosystems influenced by land-based activities. Extending several hundred kilometers seaward, the coastal zone includes offshore banks and continental shelves. Coastal waters include the major upwelling areas of the world—such as those off the coasts of Peru and the western coasts of North America and Africa—where highly productive waters support major fisheries. Functionally, it is a broad interface between land and sea that is strongly influenced by both.

Although nearshore coastal waters are a very small part of the oceans, they are often sheltered areas of high localized productivity, based primarily on the concentration and cycling of nutrients from adjacent land masses. Among their most important characteristics are the intimate links between neighboring communities, which render the whole complex more diverse and productive than any of its constituent parts. Coastal ecosystems and adjacent oceanic production are interconnected in terms of energy flow and subsidies, nutrient and mineral cycling, the movement of water and organisms, and the requirements for species of economic and/or ecological importance in one system to complete portions of their life cycles in other systems. The highly productive fisheries in the Java seas, for example, may be attributed to the increased primary productivity in ocean waters that are fed by estuarine flooding from freshwater runoff into coastal waters (19).

Coastal ecosystems play a major role in the life cycles of economically important finfish and shellfish species by providing feeding, breeding, and nursery habitat. For example, an estimated 98 percent of all fish caught in the Gulf of Mexico are estuarine dependent (20), and juvenile lobsters occupying seagrass beds are the source for a coral reef fishery that provides Belize with over 80 percent of the income from its second largest foreign exchange earning industry (21). Further, exports are only a fraction of the total catch that provides food for the majority of coastal nations' residents. Tropical Pacific islanders depend upon coastal marine resources for at least 90 percent of their protein intake (22).

Additional functions of coastal ecosystems include the critical role of buffering the joining of land to sea by moderating coastal erosion and large salinity changes. Coral reefs, for example, act as barriers dissipating wave and current energy, and mangroves, by occluding and absorbing terrestrial freshwater runoff, buffer salinity changes in coastal waters.

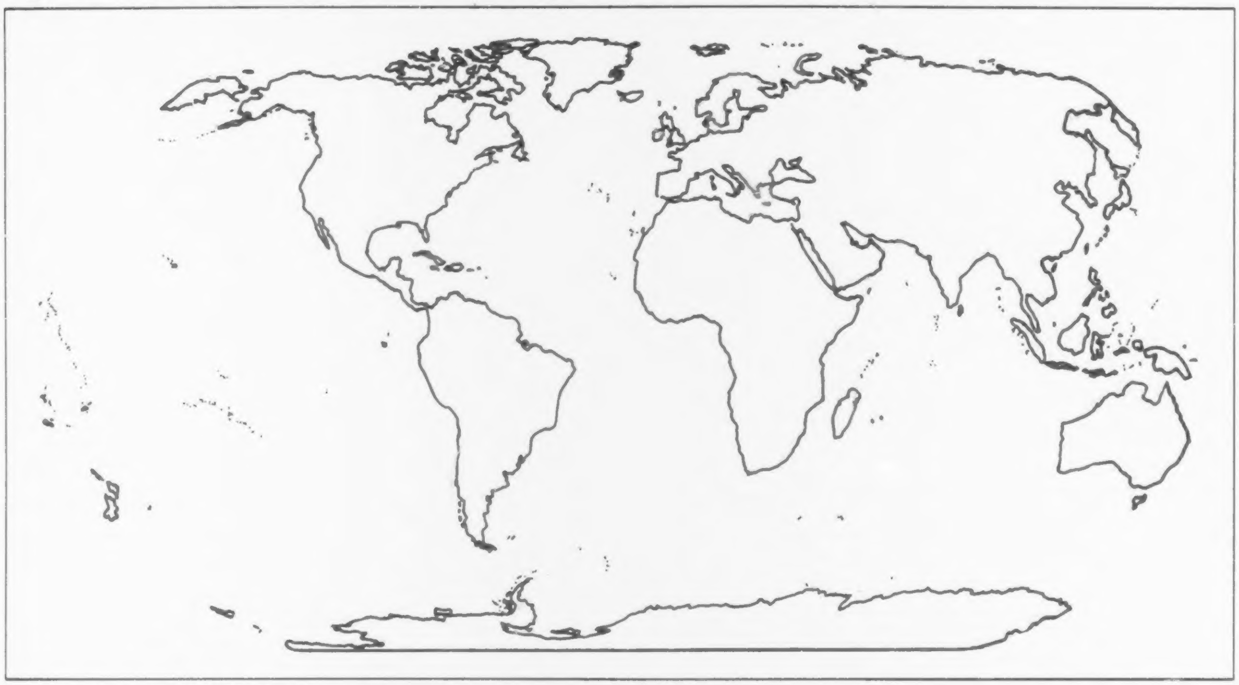
Many of the most biologically productive coastal communities are in tropical regions, where they are threatened by population and development pressures. (An estimated two thirds of the world's human population resides along coastlines and banks of rivers draining into coastal waters (23).) This section focuses on the three major resources of the coastal tropics—mangroves, seagrass beds, and coral reefs.

Mangroves

As much as 75 percent of low-lying tropical coastlines with freshwater drainage are dominated by salt-tolerant trees or shrubs known as mangroves (24). (See Figure 9.1.) There are some 240,000 square kilometers of mangrove-dominated intertidal, lagoonal, and riverine flatlands with mangrove forests reaching their greatest extent along the coasts of South and Southeast Asia, Africa, and South America (25).

Mangrove forests are one of the most productive and biologically diverse ecosystems in the world, providing habitat for more than 2,000 species of fish, invertebrates, and epiphytic plants (i.e., those that live on the surface of other plants, deriving support but not nutrients from their "host" plants) (26). Nutrients released through the decomposition of the abundant mangrove leaf and twig litter are an important direct and indirect food source for aquatic animals, including economically important fisheries species. This litter can be the first link in a long food chain terminating with open-ocean fisheries. For

Figure 9.1 Distribution of the World's Mangroves



Source: Snedaker and Getter, 1985, Reference 25

example, shrimp abundance in offshore waters increases with the size of the mangrove tidal forest nursery grounds (27). In Fiji, about half the commercial and artisanal fisheries use mangrove areas for at least one critical stage in their life cycles, and at least 83 percent of the mangrove-dependent fish species harvested are used for food (28). In eastern Australia, 67 percent of the entire commercial catch is composed of species that depend on mangrove estuarine areas, and an estimated 80 percent of all marine species of commercial or recreational value in Florida depend on mangroves for some stage of their life history (29).

Mangroves are also valuable as a source of timber, pulpwood and chips, fuel, and charcoal (30). In addition, their extensive root systems act as silt traps, stabilize shorelines, and help maintain estuarine and coastal water quality (31,32). Thailand and the United States are among the countries that deliberately cultivate mangroves to prevent shore erosion (33).

Although key pressures on mangrove ecosystems vary from country to country, by far the greatest threats are clear-cutting, diversion of freshwater from upland watersheds, and reclamation for agriculture and aquaculture (34). One major consequence of such mangrove degradation is reduced fish yields. Table 9.5 presents a preliminary list of key threats to mangroves and the regions where these threats are of greatest concern. Brackish water aquaculture has a particularly pronounced environmental impact because of the fundamental changes it creates in the mangrove environment.

In Southeast Asia, mangrove ecosystems are frequently converted to brackish water fish ponds for the culture of prawns and milkfish. In the Philippines, for example, aquaculture production—which approximately doubled between 1952 and 1977—was responsible for an estimated four fifths of the mangrove destruction that took place there between 1967 and 1977 (35,36). Similarly, in the Gulf of Guayaquil, Ecuador, an estimated 16 percent of the mangrove swamps were reclaimed for shrimp production between 1966 and 1982, with more than half the decline in mangrove area occurring between 1977 and 1982 (37). At present rates of decline, mangroves could disappear from both these areas by the mid-1990s.

In the Gambia, a proposed dam on the Gambia River is likely to reduce the existing mangrove area by about 70 percent (38). The mangrove food chain presently supports 40 percent of the total fish catch for the Gambia River estuary (39); assuming a 70 percent mangrove decline, the 40 percent would be reduced to about 12 percent. Additional examples of trends in the extent of mangroves are given in Figure 9.2 for selected countries where data are available. There are no global systematic quantitative estimates of mangroves, seagrass beds, and coral reefs destroyed or degraded over the last 10–20 years.

An awareness of the value of mangrove swamps for forestry, fisheries, and recreation has prompted several initiatives to protect mangrove ecosystems. Currently, the total area of mangrove forests under some degree of preservation represents less than 1 percent of the entire

Table 9.5 Major Causes of Recent Degradation of Mangrove Ecosystems By Region

	Indo-Pacific	South Asia	Southeast Asia	Africa	Central America	South America	Wider Caribbean
Clear-cutting	+	+	+	+	+	+	+
Firewood	+	+	+	+	+	+	+
Freshwater Diversion		+		+			
Land Reclamation:							
Agriculture	+	+	+	+			+
Aquaculture		+	+	+	+	+	+
Development:							
Urban	+	+	+	+		+	+
Industry	+		+	+			
Ports	+	+	+	+		+	+
Siltation from Land Runoff	+			+			
Mining	+		+				
Solar Salt	+	+		+	+		+
Pollutants:							
Chemical	+		+	+			+
Domestic	+		+	+			+
Oil	+		+				+
Tourism/Recreation	+			+			+

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resource. At least 18 countries have preserves that are intended to give absolute protection to mangrove ecosystems or to enhance the survival of particular species within these ecosystems. If one also includes reserves where controlled access and use are permitted for forestry, fisheries, or recreation, the number of countries with protected mangroves doubles. Yet few of these reserves are adequately managed (40).

Seagrasses

Seagrasses are salt-tolerant plants similar in appearance to their terrestrial counterparts, but they grow under water. Seagrass communities are widely distributed throughout much of the temperate and tropical coastal environments of the world, where they thrive in clear, calm, and shallow waters. (See Figure 9.3.) Tropical seagrasses are concentrated in the Indo-West Pacific and the Caribbean.

Seagrass communities are known for their ability to trap and bind sediment, thus retarding erosion of shallow water sediments. The buffering effect of seagrasses assumes additional importance in reducing turbidity and clarifying the surrounding waters, an effect beneficial not only to the seagrasses themselves but also to associated filter-feeding invertebrate communities and nearby coral reefs.

Seagrasses provide a habitat for fish and other marine organisms. They are also a source of food materials, consisting mostly of epiphytes (predominately algae) that live on the leaf surfaces and macrofauna that abound among seagrasses and in the rich layer of detritus. The primary commercial value of seagrass beds, in fact, derives from their importance as forage and critical habitat for fisheries species as well as some of their food sources. Postlarval stages of commercially important fisheries (e.g., tiger prawns in eastern Queensland, Australia) concentrate and develop in these areas (41). Seagrass beds also provide spawning grounds for adult breeding populations of fisheries species (42). It has been estimated that one hectare of seagrass in the Arabian Gulf can contribute an annual yield of as much as 850 kilograms of shrimp, a valued source of foreign exchange in many countries (43).

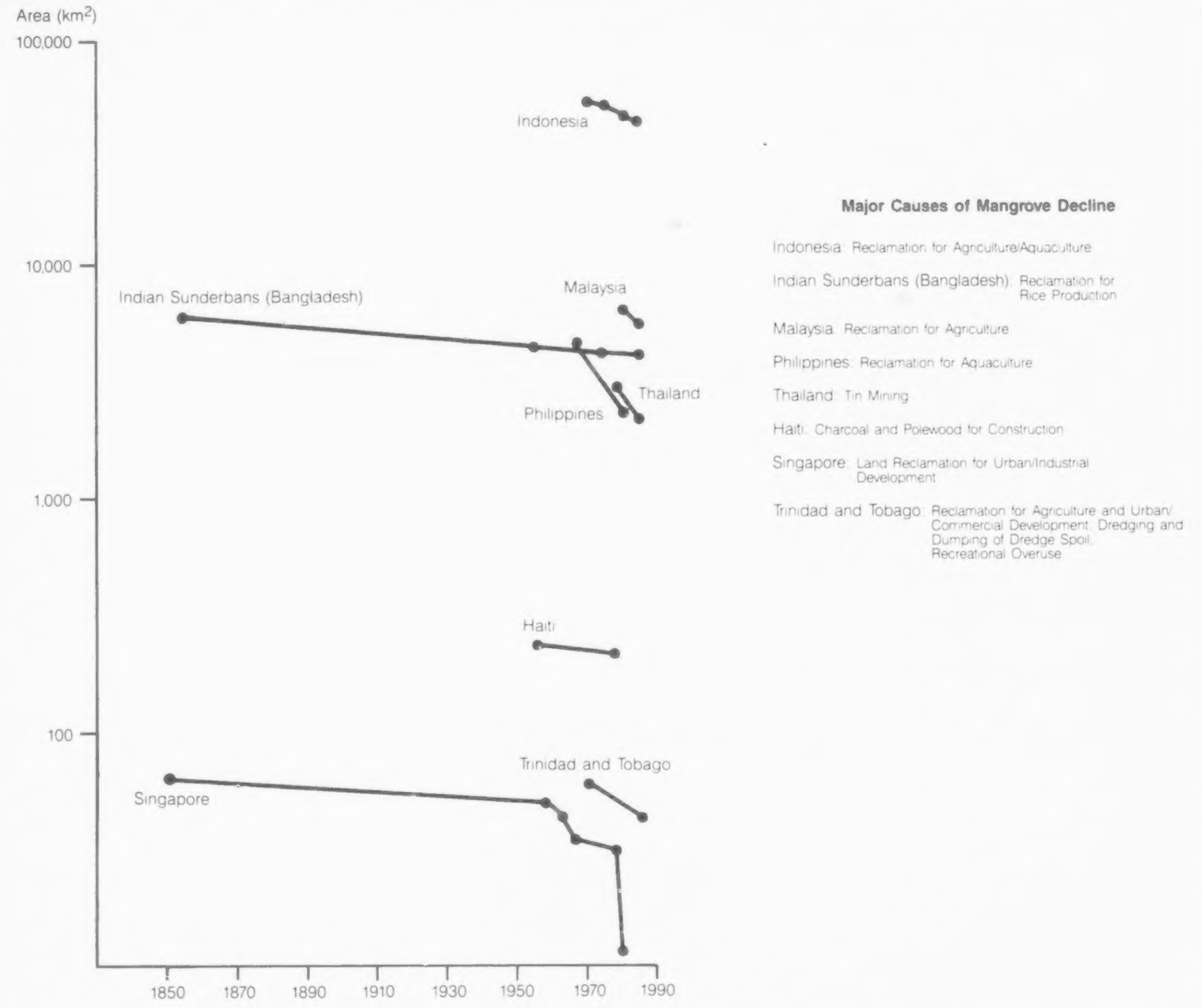
Seagrasses intermingle with both mangrove and reef communities at their respective seaward and landward boundaries. Extensive submarine meadows frequently provide the link between the environmentally different mangrove and coral reef ecotypes. The migration of animals at various life stages from one ecosystem to another for feeding and shelter, coupled with the flow of water that transports both organic and inorganic material from runoff and tidal flushing, ties the offshore coral reefs to nearshore seagrass beds, and the seagrass beds to mangrove estuaries (44).

The major threats to seagrasses are dredge and fill operations, fishing practices that use bottom trawls, and water pollution such as that caused by industrial wastes, thermal discharges from power plants, and accidental spills of petroleum products (45). (See Table 9.6.) Because baseline information on the global extent of seagrasses has not been collected, it is difficult to assess their condition and trends. However, there are a few isolated reports of damage to seagrass communities.

Preliminary mapping of seagrass cover in Western Australia indicates that seagrass beds in Cockburn Sound were reduced by an estimated 79 percent between 1954 and 1978 (46). This loss followed industrial development along the shore and coincided with the discharge of effluents from a fertilizer factory (47). Similarly, dredge and fill operations were primarily responsible for a 65.4 percent loss of seagrasses in Princess Royal Harbor and a 41 percent loss at Oyster Harbor in Australia (48).

The loss of seagrasses decreases the quantity of marine life; one study revealed five times more fish and invertebrates residing over seagrass beds than over a mud/sand/shell habitat (49). A dredge and fill operation in Boca Ciega Bay, Florida, in the United States, destroyed 20 percent of the seagrass bed, resulting in an 80 percent reduction in the number of species, and caused an estimated $1.4 million loss in fish production (50).

Figure 9.2 Trends in Extent and Major Causes of Decline in Mangroves in Selected Countries, 1850–1990



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For Thailand:

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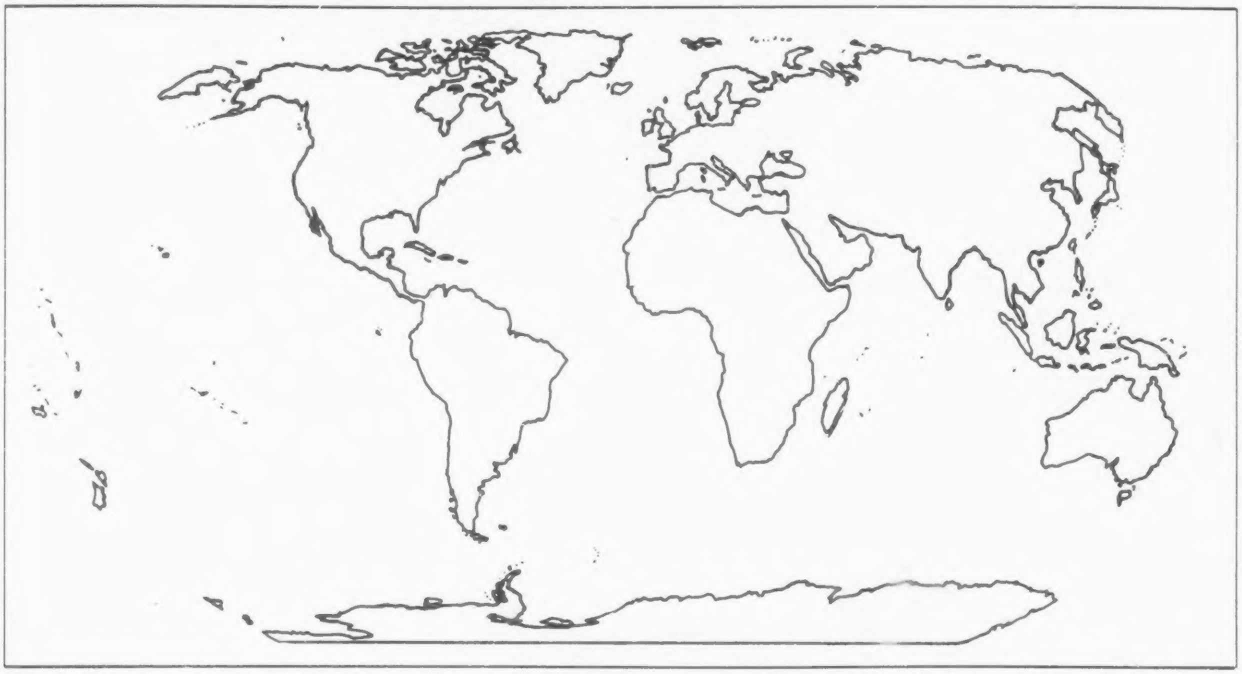
Figure 9.3 Distribution of the World's Seagrasses



Source: G.W. Thayer and M.S. Fonseca, *The Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile* (U.S. Department of the Interior, Washington D.C., 1984).

To date, no preserves have been established specifically for the protection of seagrasses, although they have sometimes benefited from adjacent habitats under protected status. Mangroves, for example, are the primary ecosystem concern of the Everglades National Park in Florida, even though seagrasses comprise about 85 percent of the submerged macro-vegetation of the coastal waters under protection. Seagrasses also dominate the Looe Key National Marine Sanctuary off the Florida coast; yet the focal point of the park is its species-rich coral reefs (51).

Coral Reefs

Stony or reef-building corals are a dominant feature of the shallow coastal marine environment in almost all areas of the tropical circumglobal belt remote from major upwellings or inflows of freshwater. Exceptions to this pattern occur where warm currents extend beyond the tropics. (See Figure 9.4.) On a global basis, coral reefs and associated communities cover an estimated 600,000 square kilometers, with 30 percent found in the "Asiatic Mediterranean" (bounded by Indonesia to the west, northern Australia to the south, the Philippines to the east, and mainland Asia to the north). An additional 30 percent is found in the Indian Ocean, Arabian Gulf, and Red Sea, 13 percent in the South Pacific, 12 percent in the North Pacific, 14 percent in the Caribbean Sea and North Atlantic, and 1 percent in the South Atlantic (52).

Coral reefs are the marine version of tropical rainforests, rivaling their terrestrial counterparts in productivity and richness of species. The 150-kilometer-long barrier reef surrounding Palau in the Pacific, for example, has nine species of seagrasses, more than 300 species of corals, and about 2,000 species of fish (53). An estimated 80 genera and 500 coral species form the Great Barrier Reef, the longest reef system in the world, stretching over 2,000 kilometers along Australia's eastern coast (54).

Approximately one third of all fish species live on coral reefs (55). Coral reefs contribute to fisheries in three ways: fishing directly on the reef; fishing in shallow coastal waters where coral reefs are critical to food webs, life cycles, and productivity; and fishing in offshore waters where the reef's high productivity may be important regionally.

Reports of fish yields from coral reefs appear to vary widely from less than 1 metric ton per square kilometer per year to almost 20 metric tons per square kilometer per year (56). Present evidence suggests that a sustainable harvest of all edible fish, crustaceans, and mollusks averaging 15 metric tons per square kilometer per year could be derived from all coralline areas less than 30 meters deep (57). The corresponding theoretical potential harvest on a global basis amounts to 9 million metric tons per year, the equivalent of 12 percent of today's total world fish production (58).

Coral reef-dependent artisanal fisheries have been reported to account for up to 90 percent of the fish production in Indonesia (59) and up to 55 percent of the reported fish catch in the Philippines in 1975 (60). This harvest contributes to more than 54 percent of the protein intake of all Filipinos (61). The importance of such fisheries as a necessary protein supply to a distinct population of small-scale fishermen and their dependents is easily obscured when dealing with fisheries on a global or even on a national level.

Coral reefs supply food for harvestable pelagic fisheries in non-reef areas as well. For example, two of three harvested tuna species near New Caledonia are known to feed primarily on coral reef fish (62), and a Solomon Island skipjack tuna fishery operated by a Japanese enterprise depends upon reef baitfish (63). Two of the most important and relatively unappreciated functions of coral reefs are their roles in coastal protection and island building. Along the southwest coast of Sri Lanka near Hikkaduwa, coral mining for a variety of construction and industrial purposes (e.g., lime, calcium carbide, and cement production) has caused serious coastal erosion (64). Concentrated exploitation of the offshore coral reefs has accelerated erosion along a six-mile stretch of coastline, from which an estimated 75,000 tons of coral are mined annually (65). As a result, the "beach" has moved 300 meters inland from its original position, whittled away by direct wave action over a 50-year period (66).

With regard to island building—even though the principal island type consists of granitic bedrock—77 percent of the *isolated islands* and *island archipelagos* in the Indian Ocean are built exclusively from reef deposits (67). The entire Maldive Archipelago, comprising 20 atolls and an estimated 2,000 coral islands, would not exist were it not for coral reefs. Without coral reefs the Seychelles would not have 47 percent of their total land area (68) or about half their 48,334 square kilometers of submarine banks (69).

Coral reefs and the associated white sand beaches are major tourist attractions in the coastal tropics. In the last 50 years, for example, the coastal-based tourist industry of the Bahamas generated 55 percent of the country's gross national product (70). Between 1972 and 1981, the number of tourist resorts in the Maldives increased from 2 to 37, and the number of overseas visitor arrivals rose to 60,358 (71).

With the increase in tourism, the international coral curio trade has grown rapidly. In 1983, for example, the Philippines exported 244 tons of coral to the United States (72). Coral collecting and mining removes the animals responsible for formation of the reef. Such a loss reduces the resistance of the reef to wave action, increases the likelihood of storm damage and beach erosion, and reduces the aesthetic qualities of the reef. The long-term effects on reef structure are not yet known. However, there seems to be a positive correlation among fish, standing biomass, and the proportion of coral cover (73).

Sediment pollution from mismanaged upland areas and destruction by mining or blast fishing are the primary threats to reef ecosystems (74). Coral mining and blast fishing are particularly destructive because most coral species grow very slowly, effectively rendering them a non-renewable resource. Additional pressures include dredge and fill operations, overfishing, water pollution, large volumes of freshwater from river diversions or storm runoff, and destruction by collectors and tourists. Starfish, particularly the crown-of-thorns starfish (*Acanthaster planci*), significantly damage reefs by feeding on the live coral. Table 9.7 is a preliminary list of key pressures to reef ecosystems, and the regions of major concern.

There are few estimates of the ecological conditions of coral reefs over the past 20 years. Various reports for specific time periods indicate that the coral cover is declining. An exception is Kaneohe Bay, Oahu, Hawaii. Surveys done there five years before and five years after most of the sewage was diverted to an offshore site show that live coral coverage in the lagoon had almost doubled (75).

The majority of reefs in the Philippines are in fair to poor condition, with two thirds of the stations sampled in 1982 having less than 50 percent live coral cover (76). This decline is attributed to siltation accompanying massive deforestation, blast fishing, and coral harvest (77). Six of the more commonly collected commercial coral species in Philippine reefs have declined by 73 percent (78).

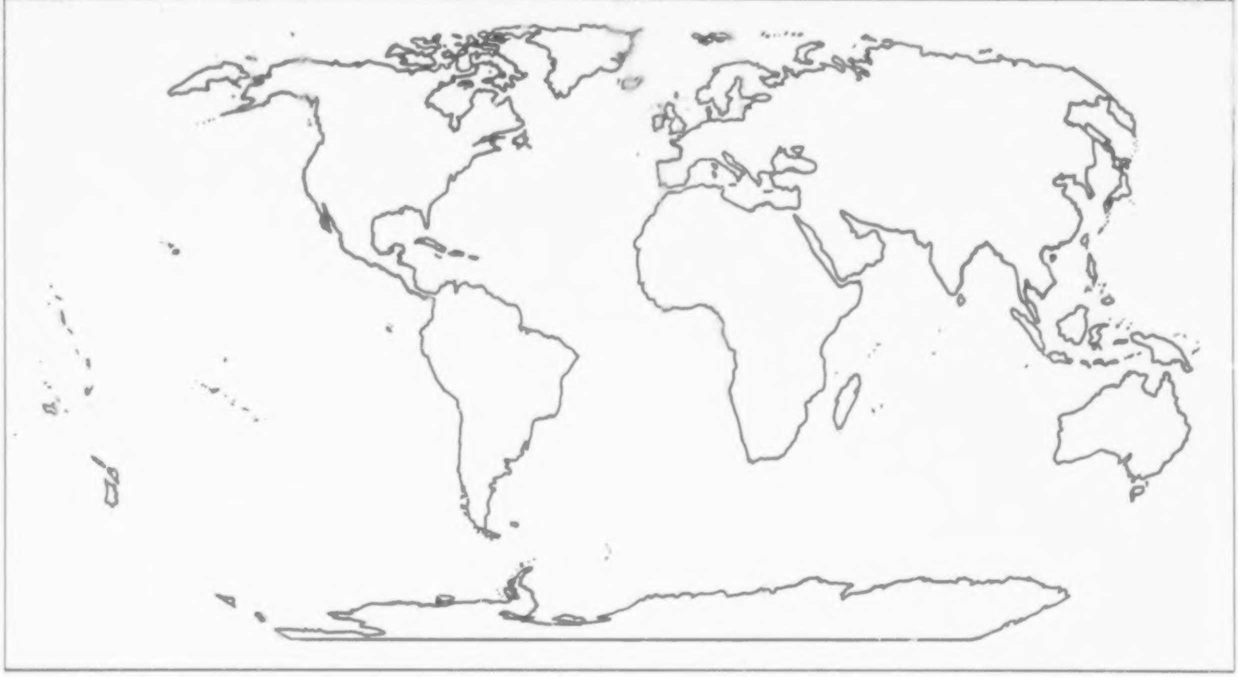
A 1984 survey of some reefs along the Tanzanian coast revealed that the luxuriant reef growth of the 1960s was reduced to rubble by extensive blast fishing. The loss of reef habitat caused the decline of a formerly lucrative

Table 9.6 Major Causes of Recent Degradation to Seagrass Ecosystems by Region

	Indo-Pacific	South Asia	Southeast Asia	East Africa	West/Central Africa	Middle East	Wider Caribbean
Direct Destruction							
Dredge/Fill	+	+	+			+	+
Trawling	+			+		+	
Siltation							
Dredge/Fill	+	+	+			+	+
Land Runoff				+	+		
Pollutants							
Chemical	+				+		+
Domestic	+						
Oil					+		+
Thermal							+

Sources:
1. G.J. Bakus, University of Southern California, Los Angeles, 1985 (personal communication).
2. N.L. Berwick, "Guidelines for the Analysis of Biophysical Impacts to Tropical Coastal Marine Resources," in *Proceedings of the Bombay Natural History Society Centenary Seminar: Conservation in Developing Countries—Problems and Prospects*, December 1983 (Bombay, India, in press, 1985).
3. E.D. Gomez, University of the Philippines, Marine Sciences Center, Quezon City, 1985 (personal communication).
4. P.N. Lal, "Environmental Implications of Coastal Development in Fiji," *AMBIO*, Vol. 13, Nos. 5-6, pp. 316-321 (1984).
5. A. Thorhaug, "Biology and Management of Seagrass in the Caribbean," *AMBIO*, Vol. 10, No. 6, pp. 295-298 (1981).
6. Zieman, 1982, Reference 42.

Figure 9.4 Distribution of the World's Coral Reefs



Source: Snedaker and Getter, 1985. Reference 25

fishery. An alarming increase in beach erosion also threatens tourist hotels in the area (79). Over the past 30 years, siltation from extensive dredging and overfishing have caused a 95 percent decline in the live coral coverage of coral reefs fringing the southern coast of Hainan Island (part of the People's Republic of China) in the South China Sea (80).

Starfish predation devastated coral reefs in the Ryukyu Archipelago of Japan in 1974 (81), causing an estimated 75 percent loss of live coral cover. Siltation from agricultural runoff, landfill, and road and hotel construction, coupled with little or no recovery from starfish predation, further decreased the live coral cover in the area to a mere 1–2 percent (82).

Although awareness of the importance and vulnerability of reef ecosystems has been growing, only about half the countries with reefs have at least one or more established and managed marine protected area. An estimated 70 percent of the countries without such reserves, however, have proposed or interim-designated marine protected areas (83).

Trends in Mangroves, Seagrasses, and Coral Reefs

The limited long-term quantitative data on these three tropical coastal ecosystems preclude assessment of the resources and areas that are critically threatened. An indirect assessment of resource vulnerability, however, can be derived from an analysis of resource abundance and development activity where data are available. (See Figures 9.5, 9.6, and 9.7). The analysis assumes that vulnerability is determined primarily by the extent of the resource, the economic capacity for exploitation of the resource, the density of the human populations available to exploit the resource, and the growth rate of these populations (85). This indirect assessment indicates that all three resources appear to be at greatest risk in Central America, followed by Southeast Asia. Overall, coral reefs appear to be the most threatened, particularly in South and Southeast Asia, followed by seagrasses and mangroves. (Also see Part IV, Chapter 10 "Oceans and Coasts," Table 10.3.)

RECENT DEVELOPMENTS

OCEAN DISPOSAL OF RADIOACTIVE WASTES

During the 1980s, public concern about the treatment and disposal of radioactive wastes has grown markedly. With ocean disposal as an option, concern has been manifested primarily through the London Dumping Convention (LDC), the global treaty that regulates the dumping of wastes in the oceans beyond the limits of national jurisdiction.

At their seventh meeting in February 1983, parties to the LDC adopted a resolution to prohibit low-level radioactive waste dumping pending a scientific review of the risks. Until that time, European countries (the United Kingdom, Belgium, Switzerland, and the Netherlands) had been dumping these wastes at a depth of 4,000 meters in a small area of the Atlantic Ocean off the coast of Spain.

At the 1984 LDC meeting, more specific terms of reference were formulated for the scientific review. The matter was again considered at the LDC meeting in London in September 1985.

Tensions and disagreements were strong between the countries opposed to dumping and those that are generating radioactive wastes and are anxious to dispose of them as soon as possible. Just before the meeting, Great Britain threatened to resume dumping even if the moratorium were not lifted; some observers felt that the United States might follow suit. In any event, these threats proved ineffective and the LDC adopted a resolution—by a vote of 25 in favor, 6 opposed, and 7 abstentions—that provides for an indefinite moratorium on low-level waste disposal pending completion of important risk-related scientific and other studies.

The six countries voting against the resolution were Great Britain and Switzerland, which both had been carrying out ocean disposal prior to the moratorium, Canada, France, South Africa, and the United States. The United States has not dumped radioactive wastes at sea since 1970, but key officials within some federal agencies—particularly the Departments of Defense and Energy—continue to promote the sea disposal option.

Central to the continuing controversy over low-level waste disposal are the difficulties of establishing a common basis for assessing the social, economic, scientific, and technological factors and of the need for a thorough assessment of the land-based versus sea-dumping options. These issues will be considered in detail by the parties to the LDC. At their next formal meeting in the fall of 1986, government members and observers will develop detailed terms of reference for carrying out the studies mandated by the 1985 resolution.

Another important decision that will limit ocean disposal of radioactive wastes was made in 1985 when the South Pacific Forum (the 13 independent and self-governing states in the Southwest Pacific) adopted the South Pacific Nuclear Free Zone Treaty (SPNFZ). The SPNFZ reflects the long-standing concerns of Forum members about testing in the region, proposals to dump nuclear wastes there, and other nuclear issues. Under the treaty, Forum members agreed not to dump radioactive wastes within the zone, not to help anyone dump wastes at sea, and to support a regional convention's preclusion of ocean dumping of radioactive wastes by anyone in the region.

FAO WORLD CONFERENCE ON FISHERIES MANAGEMENT AND DEVELOPMENT

Changes in international ocean law and the fact that catches are approaching the limits of conventional resources have directed attention toward marine fisheries. Internationally, attention culminated in the U.N. Food and Agriculture Organization's (FAO) 1984 World Conference on Fisheries Management and Development.

FAO hailed the conference as "a unique and historic occasion in the evolution of the world's fisheries." It was the first time that almost all nations in the world came together to reach agreement on a strategy for the world's fisheries. It was attended by 147 countries and 67 international fishing organizations.

The two major products of the conference were a Strategy for Fisheries Management and Development, and a set of Action Programs to implement that strategy. It is, however, difficult to see how nations will be able to use the strategy as a practical guideline to manage or develop their fisheries—most of the 116 points are unexceptional, if not platitudinous. Without some guidance on which points are important, this list risks encouraging governments to select the points that match what they

Table 9.7 Major Causes of Degradation of Coral Reefs, by Region

	Indo-Pacific	South Asia	Southeast Asia	East Asia	East Africa	Middle East	Wider Caribbean
Siltation:							
Dredge/Fill	+		+	+		+	+
Land Runoff	+	+	+	+	+		+
Destructive Fishing	+		+	+	+		+
Intense Localized Fishing Effort	+		+			+	+
Construction Materials:							
Reef Mining	+	+	+	+	+		
Sand Dredging	+	+	+	+		+	
Coastal/Offshore Mining	+	+	+				
Curio Trade	+	+	+	+	+	+	+
Tourism	+		+				+
Pollutants:							
Chemical	+	+	+				+
Domestic	+	+	+		+		+
Nuclear	+						+
Oil	+		+			+	+
Natural Stress:							
Storms	+		+				+
Predation by Starfish	+		+	+			

Sources:
1. G.J. Bakus, University of Southern California, Los Angeles, 1985 (personal communication).
2. N.L. Berwick, "Guidelines for the Analysis of Biophysical Impacts to Tropical Coastal Marine Resources," *Proceedings of the Bombay Natural History Society Centenary Seminar, Conservation in Developing Countries—Problems and Prospects*, December 1983 (Bombay, India, in press, 1985).
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4. Gomez, 1980, Reference 77.
5. P.N. Lal, "Environmental Implications of Coastal Development in Fiji," *AMBIO*, Vol. 13, Nos. 5-6, pp. 316-321 (1984).
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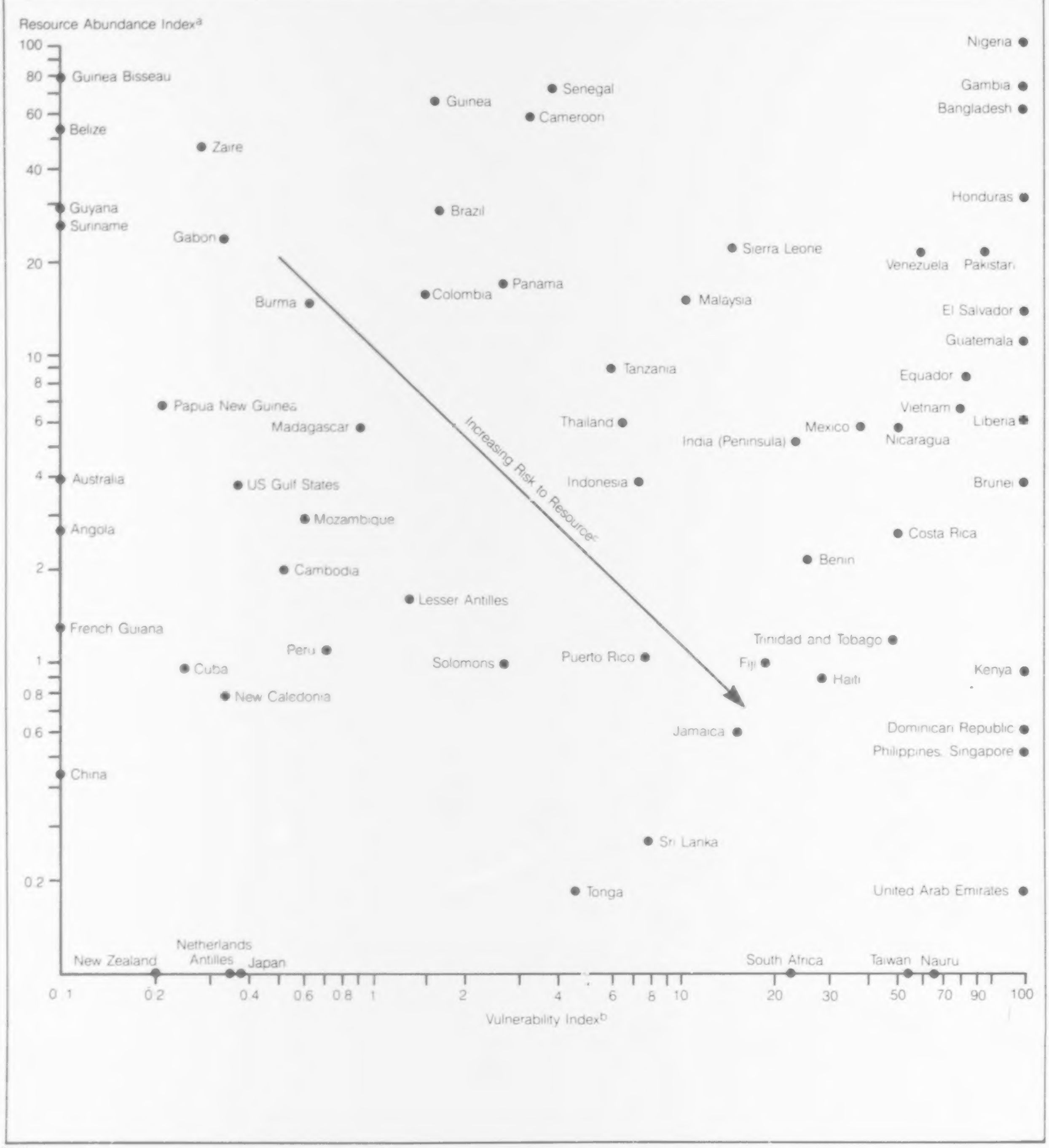
Figure 9.5 Comparative Abundance and Vulnerability of Mangroves, by Country



Notes:

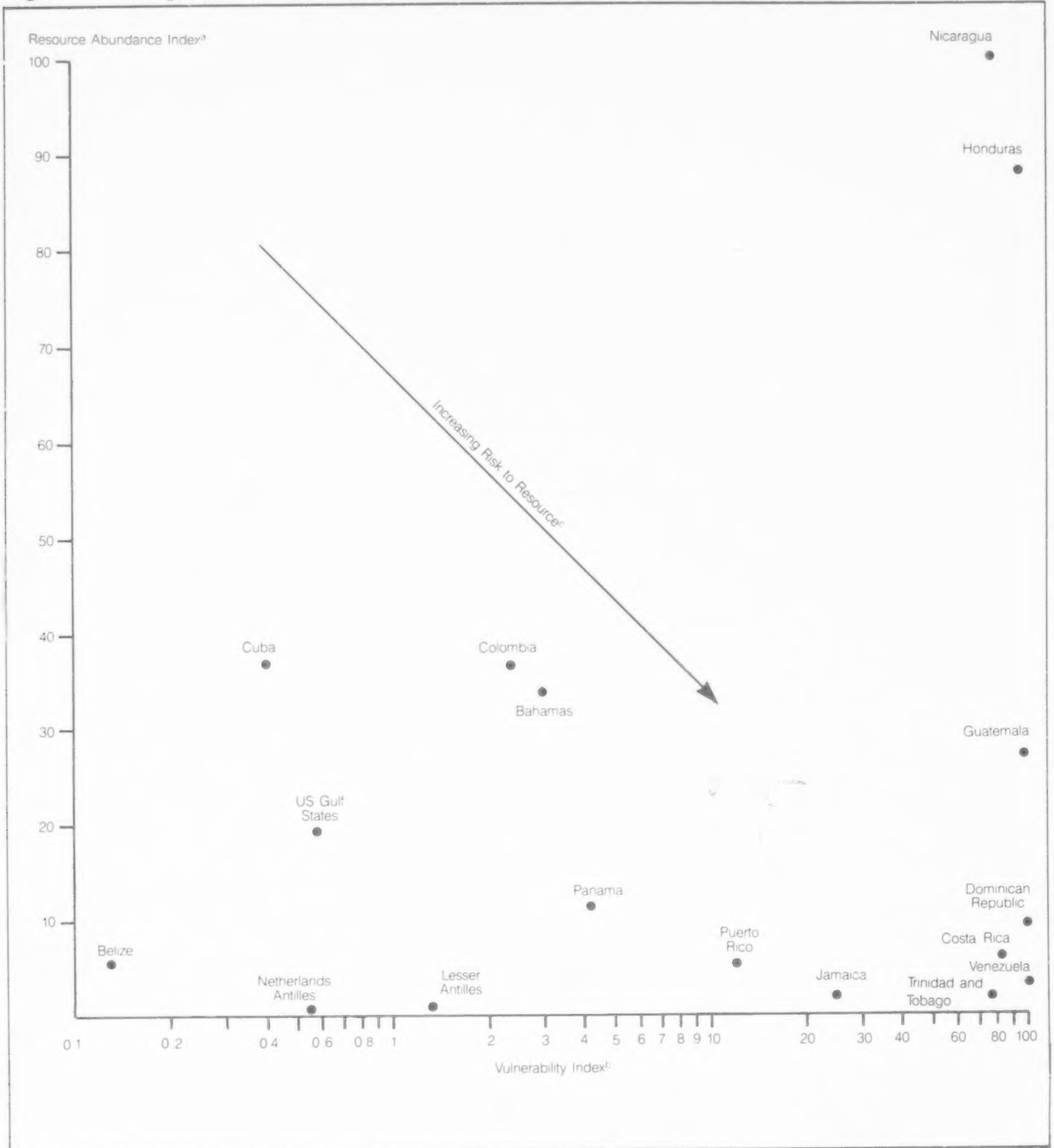
a. The resource abundance index was calculated by dividing the area of mangroves by the country coastline length and then normalizing the results to a 0-100 scale.

b. The vulnerability index was calculated by multiplying the gross national product per capita for each country by the population density raised to the power of the natural rate of increase; again, the results were normalized to 100.

c. The potential risk to the resource increases with decreasing areal extent and increasing probability of development.

Source: N.L. Berwick, *Global Assessment of Tropical Nearshore Living Resources: Patterns, Processes, Policy and Impacts* (World Resources Institute/International Institute for Environment and Development, Washington, D.C., unpublished monograph, submitted, 1985).

Figure 9.6 Comparative Abundance and Vulnerability of Seagrass Beds, by Country



Notes:

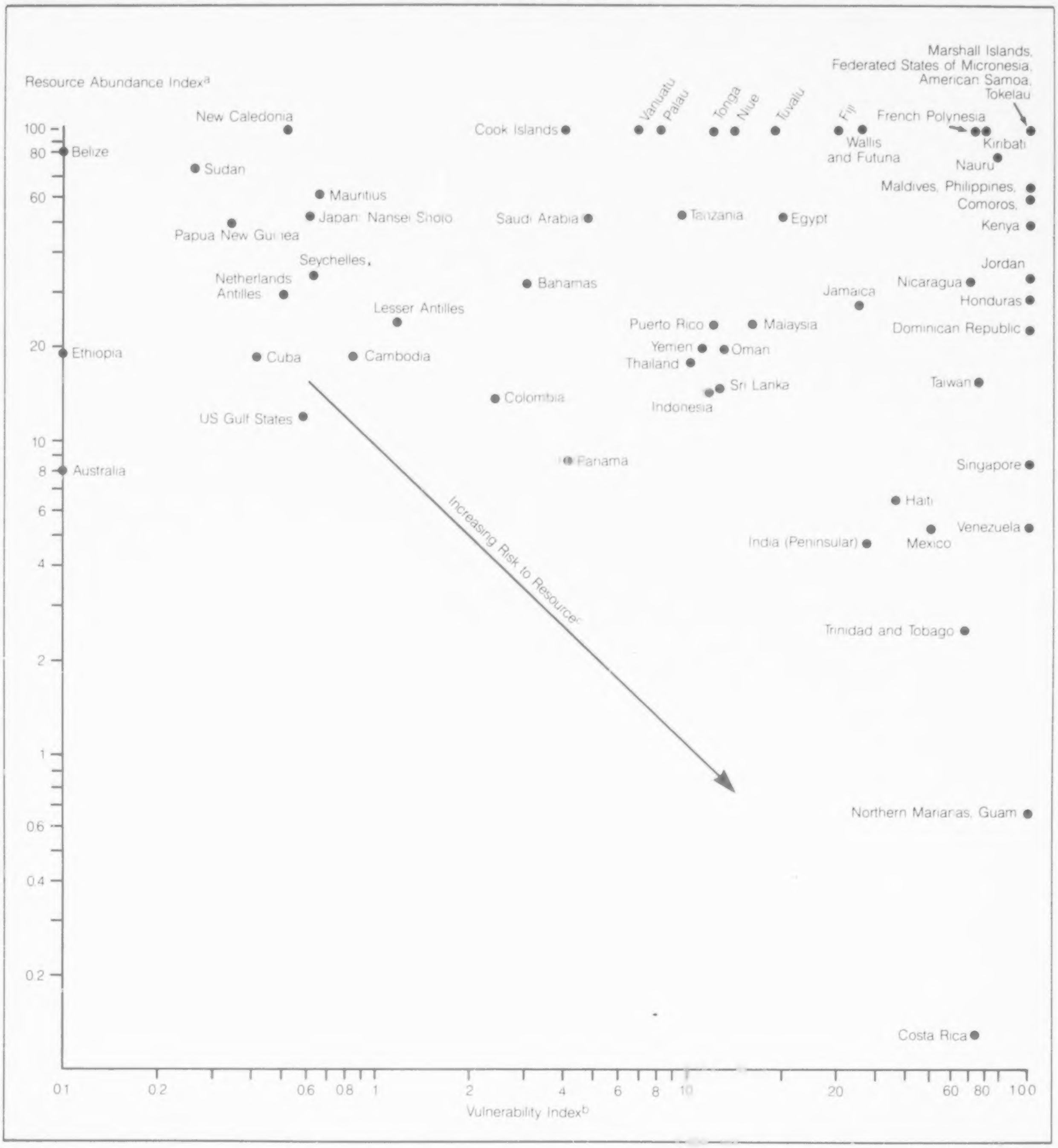
a. The resource abundance index was calculated by dividing the area of seagrass beds by the country coastline length and then normalizing the results to a 0-100 scale.

b. The vulnerability index was calculated by multiplying the gross national per capita for each country by the population density raised to the power of the natural rate of increase; again, the results were normalized to 100.

c. The potential risk to the resource increases with decreasing areal extent and increasing probability of development.

Source: N.L. Berwick, *Global Assessment of Tropical Nearshore Living Resources: Patterns, Processes, Policy and Impacts* (World Resources Institute/International Institute for Environment and Development, Washington, D.C., unpublished monograph, submitted, 1985).

Figure 9.7 Comparative Abundance and Vulnerability of Coral Reefs, by Country



Notes:

a. The resource abundance index was calculated by dividing the linear extent of coral reefs by the country coastline length and then normalizing the results to a 0-100 scale.

b. The vulnerability index was calculated by multiplying the gross national product per capita for each country by the population density raised to the power of the natural rate of increase; again, the results were normalized to 100.

c. The potential risk to the resource increases with decreasing areal extent and increasing probability of development.

Source: N.L. Berwick, *Global Assessment of Tropical Nearshore Living Resources: Patterns, Processes, Policy and Impacts* (World Resources Institute/International Institute for Environment and Development, Washington, D.C., unpublished monograph, submitted, 1985).

are already doing, and does not challenge governments to critically examine present policies and make the drastic changes that are often needed.

The action programs, which are intended to assist developing countries in implementing the strategy, were estimated to require an expenditure of $15 million over a five-year period, and the conference urged bilateral and international donor agencies to provide the necessary support. Even if the money is forthcoming, it will provide only a beginning. Changes that involve major restructuring of national fisheries may require much larger sums. At the minimum, better management will require better trained people in stock assessment, economic analysis, and probably most of all in the new profession of fisheries management. If world fisheries are to be managed on a sustainable basis, much more work is going to be required.

THE ANTARCTIC

As the last major part of the earth's surface that is still relatively undisturbed, the Antarctic continent has received increasing attention from conservationists in recent years. Human activities on this continent have been governed by the 1959 Antarctic Treaty. In addition, to promote conservation in the Antarctic, parties to the Antarctic Treaty concluded the Convention for the Conservation of Antarctic Seals (1972) and the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR, in 1980); both are in force.

Four issues are the subject of much recent discussion: the effectiveness of CCAMLR; the potential impacts of mineral exploitation; further development of protection measures; and increasing activity levels and concentrations, particularly where land or ice meets the sea.

CCAMLR, which held its fourth annual session at Hobart, Australia, in September 1985, has moved more slowly toward effective conservation measures than some had hoped, but perhaps no more slowly than other comparable international organizations. Although in many ways it is similar to several international fishery commissions, CCAMLR is the first commission to be charged specifically with consideration of the ecosystem as a whole, rather than of individual species, when making decisions. This is a considerable undertaking, but CCAMLR is moving toward the task effectively and has, among other actions, set up a subcommittee within the scientific committee to study ecosystem monitoring.

A particular disappointment is CCAMLR's slowness in applying effective measures to conserve fish stocks, some of which, especially Antarctic cod (*Notothenia rossii*), were depleted by heavy fishing from 1969 onward (86). The Soviet Union, for example, took half a million tons of Antarctic cod between 1969 and 1971. Subsequent catches have averaged only a few thousand tons annually. Current cod stocks are reported to be only a few percent of their former level (87). However, to a large extent these stocks were depleted prior to CCAMLR, and current management actions are little more than locking the stable door after the horse has fled.

Another concern is data. Many scientists, especially from non-fishing countries, have asked for detailed information on fishing operations in order to monitor changes in fished stocks. The fishing countries are unwilling to supply all these data because of the work involved. Further, it is not clear how useful such detailed information would be. How much data will actually be supplied is not known.

Fortunately, this matter has become less urgent with the decline in the krill fishery. After reaching a peak of over half a million metric tons in 1981–82, total catches have fallen to less than 130,000 metric tons in 1983–84 in the Soviet fishery, largely for technical reasons (88).

Conservation of the coastal zones received considerable attention at a symposium organized by the International Union for Conservation of Nature and Natural Resources (IUCN) and the Scientific Committee on Antarctic Research (SCAR) in Bonn in April 1985. The fringes of land along the Antarctic peninsula, a few other parts of the continent, and the Antarctic and sub-Antarctic islands are the only parts of Antarctica where any significant life exists on land. But the most easily accessible land and ice shelf areas are those that are most attractive both for human activities and for the large populations of penguins and marine mammals such as seals. These and the adjacent inshore areas are particularly vulnerable to human disturbance. Through its measures on conservation, the Antarctic Treaty already prohibits many activities that could disturb the ecosystem. However, there is a fear that even non-exploitative activities, such as the presence of many tourists or those engaged in scientific work, can be harmful, and consideration of further protective measures is being given within the Antarctic Treaty mechanism and by IUCN and SCAR. Such measures include the identification of additional protected areas, measures to deal with increased activity in Antarctica, and attention to data management.

In the long term, the greatest threat to the Antarctic environment is likely to come from mineral exploration and exploitation. No commercially attractive deposits have yet been identified. Moreover, the extreme physical conditions would make any such activity extremely costly, although the discovery of large concentrations of valuable minerals and shifts in technology or market factors could eventually make some forms of mineral extraction attractive. Recognizing that negotiations on this subject are bound to be long and difficult, the Antarctic Treaty powers are now engaged in discussions, begun in 1982, to negotiate a formal agreement similar to those on seals and marine living resources.

COASTAL RESOURCE MANAGEMENT IN THE ASEAN COUNTRIES

Resource use and management of coastal margins has always been practiced, but comprehensive, integrated coastal zone management and development were formalized only in the early 1970s. Recent coastal management activities and policy reform have been particularly prevalent among the coastal nations of Southeast Asia. They include:

- Adoption of a United Nations Environment Program Regional Seas Action Plan in April 1981 by the five member states of the Association of Southeast Asian Nations (ASEAN)—Indonesia, Malaysia, the Philippines, Singapore, and Thailand—paved the way for broader cooperation on common environmental concerns. The priority projects of the Action Plan during its initial phase in 1982–83 included: combatting oil pollution from offshore and onshore activities and from tanker traffic, reducing coral reef destruction from blast fishing, halting destruction of mangrove swamps by fish pond operators and loggers, and installing sewage treatment plants along coasts where shellfishing is predominant. The ultimate goal of the Action Plan is the incorporation of environmental considerations into all aspects of economic development in the region. If successful, the Action Plan is expected to act as a nucleus for the development of a wider program in the area that would encompass the states bordering on the Bay of Bengal, South China Sea, East China Sea, and northern Australia, in addition to the five nations already participating.
- Implementation of the five-year ASEAN/U.S. Agency for International Development (U.S. AID) Coastal Resources Management Project in 1986 strengthened the capability of ASEAN countries to manage their renewable coastal resources on a sustainable basis by improving technical and institutional approaches to managing living coastal resource systems. In order to accomplish this goal, an intersectoral and interdisciplinary systems approach to collecting, analyzing, documenting, and disseminating information on trends in living coastal resources exploitation is being carried out. These efforts are coupled with developing institutional arrangements that link applied environmental and socioeconomic research to coastal resources assessment, planning, and management.
- Additional joint ASEAN/bilateral donor assistance programs are being developed for various elements of ASEAN's cooperative program on marine sciences. The Canadian International Development Agency (CIDA) has signed a Memorandum of Understanding with ASEAN for studies on resource management and development and for pollution monitoring programs, although final arrangements for funding are not complete. Similarly, Canada's International Development Research Center (IDRC) is pursuing arrangements for providing further support to ASEAN in the marine sciences sector, particularly by strengthening the regional environmental study centers. Official responses from Japan and the European Economic Community (EEC) are reportedly in progress. As part of the ASEAN/Australia program, a project to generate quantitative baseline information on the community structure, distribution, and productivity of coastal ecosystems, with particular emphasis on mangroves, coral reefs, and interecosystem relationships, has been defined.
- Multilateral donor assistance will continue to include the United Nations Environment Program (UNEP) support to the Coordinating Body on the Seas of East Asia, and the Asian Development Bank's fisheries and aquaculture development program.
- The proposed U.S. AID-sponsored Aquatic Resource Development Project for Indonesia will focus on fisheries development and marketing, shrimp aquaculture, and a model integrated coastal resource research project. A major feature of the project is policy and institutional structural development to ensure sustainable fisheries management by considering impacts on other coastal resources.

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85. With limited quantitative data on the ecological conditions of the three tropical coastal ecosystems under scrutiny, an attempt was made to define resource abundance and vulnerability of each resource to anthropogenic change. The analysis involved devising a normalized resource abundance index and plotting it against a normalized "vulnerability" index for each of the 96 countries where data were available. The resource abundance index was calculated by dividing the areal extent of mangroves and seagrasses, and the linear extent of coral reefs, by the country coastline length and then normalizing the results to a 0–100 scale. The "vulnerability" index was calculated by multiplying the GNP per capita for each country by the population density raised to the power of the natural rate of increase; again the results were normalized to 100.

    Assumptions

    It was assumed that:

    1. Resource vulnerability is positively correlated with a low abundance and a high probability of human-induced modification.
    2. The potential for human modification is a function of population density, the rate of increase of the population, and the economic capacity for development as measured by GNP per capita; this index also constitutes an attempt to project future conditions in the face of a spotty literature on trends.
    3. The variables that contribute to growing resource consumption and environmental degradation are multiplicative rather than additive (Ehrlich *et al.*, 1977, Reference 55), and the growth rate is an exponential function.
    4. There existed a 1.5:1 ratio of reef resource to coastline length for "small" islands of less than 3,000 kilometers and therefore exclusive of "continental" islands such as Borneo and New Guinea, where no data were available.

    The fourth assumption was based upon measurements of the linear dimension of reef as a function of coastline length for 27 volcanic and coral islands in Eastern Polynesia, and 107 of the more than 300 islands comprising Fiji. The 1.5:1 reef resource to coastline length was used for the thousands of poorly mapped and little-known Indo-Pacific islands that, for purposes of initial calculations, were assumed to have a coastline length of 1 kilometer unless the literature indicated otherwise. This is particularly significant when applied to the over 3,000 islands of the Marshalls and Carolines. This assumption awaits confirmation through more detailed inspection of charts and remote sensing data. Detailed measurements conducted during a resource inventory of Ponape indicate a 1.1:1 ratio and the range of variability for this assumption.
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10. Atmosphere and Climate

Because air is a natural resource of environmental, economic, and social importance, it needs to be protected and managed (1). The driving force for monitoring, understanding, and controlling air quality is concern for both the environment and human health. No longer is air pollution seen as merely a local problem; it has regional, national, and international ramifications. Noxious emissions are often transported long distances and across national boundaries.

CONDITIONS AND TRENDS

EMISSIONS AND AMBIENT AIR QUALITY

On a global scale, various natural sources are responsible for a large proportion of the gases and particles emitted in the atmosphere. Nonetheless, in industrialized, urban, and densely populated areas, human activities are responsible for the vast majority of the air pollutants.

Programs exist in most industrialized countries to routinely monitor and assess air quality conditions, to observe trends, and to begin assessing the relationship between pollution and human health. Data from some of these national networks have become the information base for the global air quality network operated by the United Nations Environment Program (UNEP) in cooperation with the World Health Organization (WHO). Data from member states also provided information for the Organization for Economic Co-operation and Development (OECD) *State of the Environment Report 1985*. The major global, regional, and national monitoring networks are summarized in Table 10.1.

As of 1980, the UNEP Global Environmental Monitoring System (GEMS) network consisted of about 136 sites in 33 countries, but since then it has expanded considerably: today there are about 175 sites in 70 cities located in 42 countries (2). Table 10.1 lists the site classification and distribution. Although most of the monitoring sites are located in the OECD countries of Europe, North America, and the Pacific, many of the new sites are located in Third World cities. However, data from these sites will not be available for several years.

Globally, the traditional air pollutants of concern include: sulfur dioxide, nitrogen oxides, carbon monoxide, particulates, oxidants (ozone), volatile organic compounds, and lead. SO_2 and suspended particulate matter (SPM) are most commonly associated with fossil fuel combustion and, therefore, are used as indicators of pollution in urban environments. They are also the focus of UNEP's global monitoring network.

Ambient Standards and Guidelines for Pollutants

For the protection of human health and the environment, ambient guidelines have been established for major pollutants. However, exposure of individuals, and hence their health risks, are difficult to estimate because individuals

Table 10.1 Major Monitoring Networks

Sponsor	Scale	Classification of Site	Type of Monitoring/Data	Pollutant	Period of Trend Analysis
GEMS[a]	Global	Urban[b] Suburban[c]	Air Quality	SO_2 SPM	1975-83
Organization for Economic Co-operation and Development (OECD)[d]	Regional		Air Quality Emissions	SO_2 SPM NO, CO	1970-79 1979-84
United States	National	Urban Suburban Rural	Air Quality Emissions	SO_2 O_3 NO_x Pb CO	X
Japan	National	Urban Rural	X	SO_2 O_3 NO_x CO HC	X

SO_2 = sulfur dioxide, SPM = suspended particulate matter, NO_x = nitrogen oxides, CO = carbon monoxide, O_3 = ozone, Pb = lead, HC = hydrocarbons
X = not available

Notes:

a. Global Environmental Monitoring System
b. 60 percent of sites are city center, of which 50 percent are commercial, 25 percent industrial, and 25 percent residential
c. 40 percent of sites are suburban, of which 50 percent are industrial, 50 percent residential, and very few commercial
d. Not technically a network. Member countries submit data to OECD for compilation, but there is no formal network as in the other examples

Source: Compiled by World Resources Institute

move through various "zones" of different air quality, both indoors and outdoors (3). Table 10.2 lists the guidelines for SO_2 and SPM exposure limits developed by the World Health Organization to protect human health.

In addition to WHO guidelines, several countries have established their own national standards. The United States, for example, has National Ambient Air Quality Standards (NAAQS) for the major "criteria" pollutants. NAAQS are categorized as primary, or health-related standards, and secondary, or welfare-related (i.e., vegetation, materials, and visibility) standards. (See Table 10.3.) NAAQS are approximately comparable to the upper values of WHO guidelines (4).

Some of the air pollutants of concern to society are described individually in the following sections (5,6,7,8,9).

Sulfur Dioxide (SO_2)

Sources. In North America, Europe, and many other industrialized areas, more than 90 percent of all sulfur in the ambient air comes from man-made emissions. The energy sector is the principal source of SO_2 emissions, principally from the combustion of coal and oil at power plants and secondarily from industrial processes. Among the OECD countries, only in Canada and Norway is the bulk of SO_2 emissions from the industrial sector, namely from smelters.

Table 10.2 World Health Organization (WHO) Guidelines for Exposure Limits for SO_2 and Suspended Particulate Matter (SPM)

	SO_2^a ($\mu g/m^3$)	SPM ($\mu g/m^3$) Smoke Shade Method	SPM ($\mu g/m^3$) Gravimetric High Volume Method
Yearly arithmetic average[b]	40-60	40-60	60-90
98th percentile of the daily averages[c]	100-150	100-150	150-230

Notes:

a. The range (i.e., 40-60 $\mu g/m^3$) reflects scientific uncertainties about where adverse health effects are likely to begin
b. Yearly arithmetic average applies to long-term exposures
c. 98th percentile of the daily averages refers to short-term exposures and risks

Source: United Nations Environment Program (UNEP)/World Health Organization (WHO), *Sulfur Oxides and Suspended Particulate Matter*, Offset Publication 57 (WHO, Geneva, 1979).

Emission trends. The pattern of fuel use generally coincides with emission trends. In a general sense, SO_2 emissions decreased in almost all OECD countries from 1970–79, remaining stable in just a few countries. Figure 10.1 illustrates the pattern of U.S. emissions of SO_2 and NO_x from 1900–80. After a gradual increase from 1940–70, U.S. sulfur emissions decreased 36 percent from 1970–83. The downward trend in emissions continued for

Table 10.3 U.S. National Ambient Air Quality Standards

Pollutant	Primary (Health-Related) Averaging Time	Primary (Health-Related) Concentration	Secondary (Welfare-Related) Averaging Time	Secondary (Welfare-Related) Concentration
SPM	Annual geometric mean	75 $\mu g/m^3$	Annual geometric mean	60 $\mu g/m^{3a}$
	24-hour	260 $\mu g/m^3$	24-hour	150 $\mu g/m^3$
SO_2	Annual arithmetic mean	(0.03 ppm) 80 $\mu g/m^3$	3-hour	1300 $\mu g/m^3$ (0.50 ppm)
	24-hour	(0.14 ppm) 365 $\mu g/m^3$		
CO	8-hour	(9 ppm) 10 mg/m^3	Same as primary	
	1-hour	(35 ppm) 40 mg/m^3	Same as primary	
NO_2	Annual arithmetic mean	(0.053 ppm) 100 $\mu g/m^3$	Same as primary	
O_3	Maximum daily 1-hour average	(0.12 ppm) 235 $\mu g/m^3$	Same as primary	
Pb	Maximum quarterly average	1.5 $\mu g/m^3$	Same as primary	

SPM = suspended particulate matter, SO_2 = sulfur dioxide, CO = carbon monoxide, NO_2 = nitrous oxide, O_3 = ozone, Pb = lead

Note: a. This annual geometric mean is a guide to be used in assessing implementation plans to achieve the 24-hour standard of 150 $\mu g/m^3$

Source: U.S. Environmental Protection Agency (EPA), 1985. Reference 5.

most OECD countries through 1984, including the United States, where emissions decreased by 19 percent. In the Federal Republic of Germany, trends in SO_2 emissions follow a pattern similar to the one observed in the United States: emissions increased from 1950 until around 1970, with a noticeable decline beginning in the mid-1970s (10,11). (See Figure 10.2.) Figure 10.3 illustrates the share of emissions of four of the major air pollutants in the three OECD regions in 1980.

While fuel combustion and industrial production have been increasing on the whole, downward trends in emissions can be attributed to decreased reliance on fossil fuels, with increased use of nuclear power, wider use of low sulfur fuels, energy conservation, and installation of some pollution control equipment (e.g., flue gas desulfurization).

Air quality trends. In the GEMS air quality monitoring network, the predominant trend for long- and short-term ambient SO_2 concentrations for 1973–80 is downward (12,13). (See Table 10.4.) More specifically, SO_2 concentrations decreased through the 1970s in large and industrialized cities of North America, the OECD Pacific region, and many European countries, except for Italy, where concentrations increased (14). (See Table 10.5.)

Suspended Particulate Matter (SPM) (15)

Sources. Although natural sources of particulate matter are important, especially in arid regions with terrigenous soil and dust, artificial sources are of greater concern because particles have the potential for carrying toxic (including carcinogenic) trace substances, and the particulates themselves may be toxic. Fine particulates (aerosols) can be formed in the atmosphere as secondary pollutants from gaseous emissions.

The principal anthropogenic contributors to particulate matter include industrial processes and fuel combustion from stationary and mobile sources (especially diesel engines).

Emission trends. Despite economic growth, levels of SPM emissions have declined significantly from 1970–79 in major OECD countries like the United States, Japan, France, Germany, and the United Kingdom. Since 1979, economic growth has begun to slow down, and there have been further decreases in SPM. More specifically, total SPM emissions in the United States decreased by 69 percent from 1940–70 and since then have decreased another 62 percent. Table 10.6 summarizes U.S. emission estimates for the primary pollutants from 1940–83.

Such dramatic reductions are the result of changing energy policies that stress the use of coal washing equipment, conservation of energy, and the installation of dust control equipment. However, these impressive emission reductions have been offset by a corresponding increase in motor vehicle traffic since the 1960s. Further, the use of diesel cars has increased in several OECD countries, and diesel engines generate significantly higher emissions of fine and toxic particulates.

Air quality trends. The data indicate that the predominant trend for SPM concentrations at GEMS sites showed some improvement (16): 45 percent of the sites have decreasing annual averages; 10 percent of the sites show an upward trend for annual averages; and 50 percent of the industrial sites show a downward trend. (See Table 10.4.)

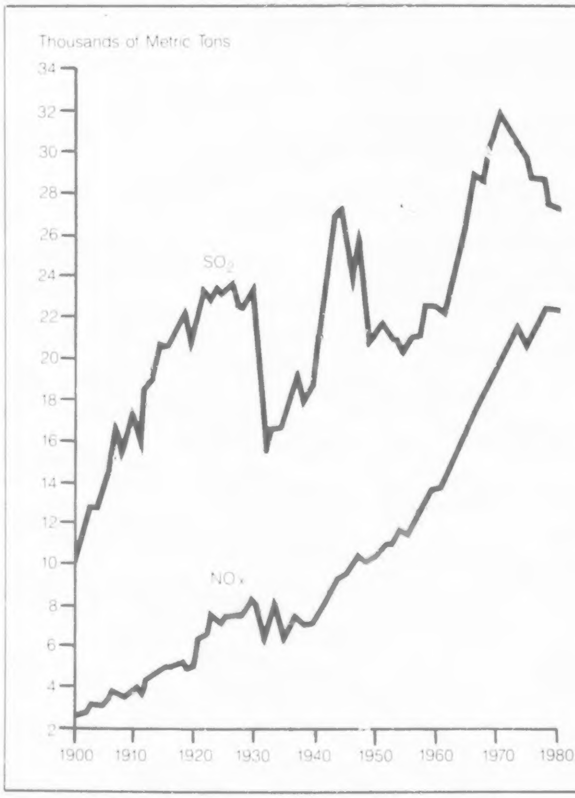
Likewise, in most OECD cities, the ambient particulate concentration from 1975–79 either fell or remained relatively stable. (See Table 10.7.) SPM levels decreased 20 percent in the United States from 1975–83 (17); in the Federal Republic of Germany, SPM concentrations decreased by 55 percent over the past two decades (18).

Overall Trends in SO_2 and SPM Pollution

At the 52 sites in the GEMS network where SO_2 and SPM concentrations were measured simultaneously for at least 5 years, 30 percent showed decreasing annual average concentrations of both pollutants; 20 percent of the sites had stationary trends for both pollutants; and none of the sites showed upward trends for both pollutants (the remaining sites showed mixed trends).

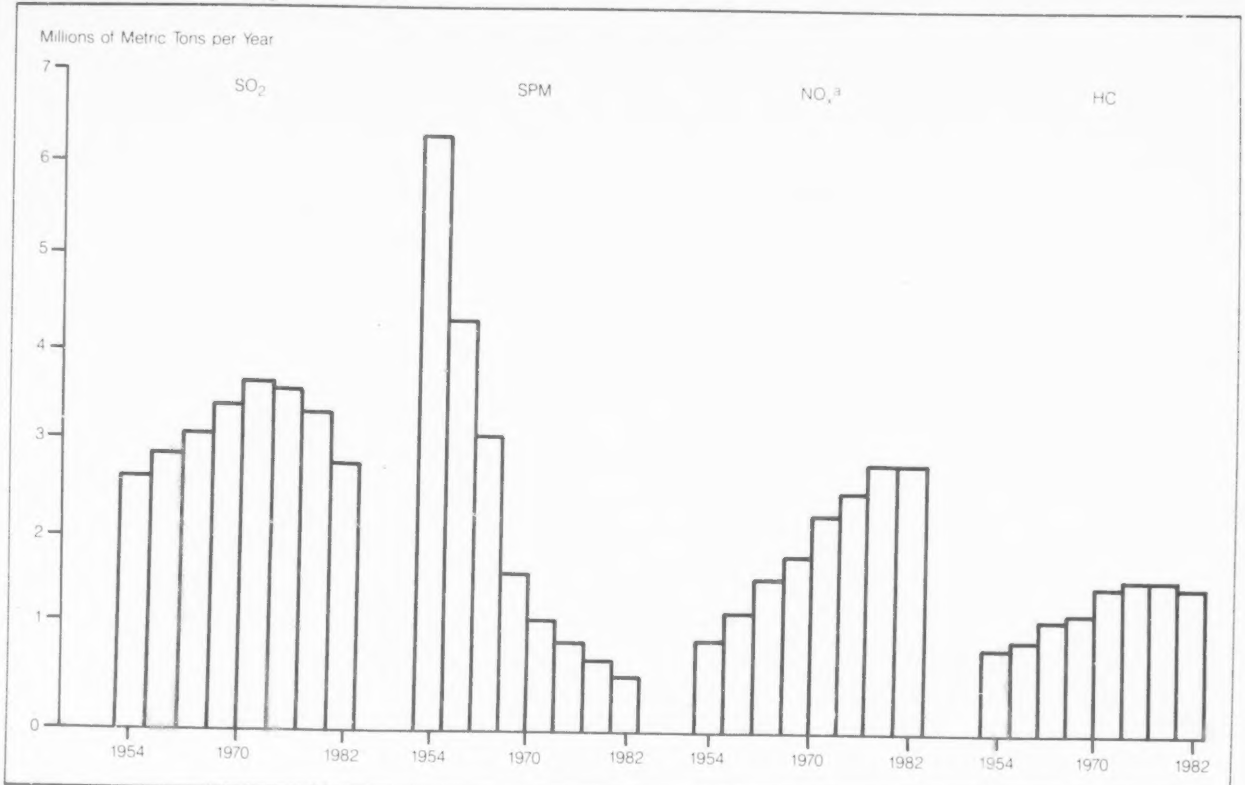
Sulfur dioxide and SPM pollution levels were also compared for cities in the GEMS network using only data representing substantially complete measurements at several sites within a city for 1976–80. The composite average was then calculated and plotted along with the

Figure 10.1 Annual Emissions of SO_2 and NO_x in the Coterminous United States, 1900–80



Source: U.S. Environmental Protection Agency, 1985. Reference 5

Figure 10.2 Estimated Emissions of SO_2, SPM, NO_x, and Hydrocarbons in the Federal Republic of Germany, 1954–82



Note: a. Calculated as NO_2.
Source: Federal Republic of Germany, Federal Ministry for Research and Technology, 1984. Reference 10.

range of annual averages at individual sites. (See Figures 10.4 and 10.5.) Composite SO_2 averages range from 17 micrograms per cubic meter for Auckland, New Zealand, to 207 micrograms per cubic meter in Milan, Italy. However, with SPM concentrations, the ranges among individual sites in each city are tighter. The composite averages extend in a fairly regular fashion from 59 micrograms per cubic meter in Tokyo to 142 micrograms per cubic meter in Zagreb, Yugoslavia. The unusually high average SPM concentrations for Tehran, Iran, and Calcutta, India, are not due entirely to industrial pollution; naturally high dust levels also contribute (19).

By and large, 1980 data from the GEMS network indicate that cities in Eastern Europe and the Third World are consistently more polluted with SO_2 and SPM than most (but not all) of the cities in OECD countries. Monitored cities in developing countries exhibited relatively higher values for suspended particulate matter than any of the OECD countries, with particularly high maximum values (ranging from 525 micrograms per cubic meter up to 2,221 micrograms per cubic meter) in Baghdad, Iraq; Teheran, Iran; Bombay, Calcutta, and New Delhi, India; Jakarta, Indonesia; Lahore, Pakistan; and Kuala Lumpur, Malaysia. These high levels are attributed to a combination of sources, mostly urban wood and charcoal fires for cooking, heating water, and fueling cottage industries (20).

Smoke concentrations (another way of measuring SPM) were also high in the South American cities of São Paulo, Brazil; Santiago, Chile; and Bogotá, Colombia (21). Since data for these countries are relatively recent (1975–80), it is not possible to detect long-term trends in air quality. However, available data indicate that smoke and particulate pollution are becoming serious problems in many Third World cities.

A similar picture emerges in Eastern Europe. High levels of smoke pollution in the range of 570–830 micrograms per cubic meter maximum values have been noted in East Berlin, German Democratic Republic; Prague, Czechoslovakia; Zagreb, Yugoslavia; and two cities in Poland, Warsaw and Wroclaw (22).

Once again the available data are too patchy to detect trends, but it seems apparent that Eastern Europe, in general, suffers from relatively higher levels of both SO_2 and SPM pollution than cities in OECD countries (23).

Nitrogen Oxides (NO_x)

Sources. The major anthropogenic sources of NO_x are the transportation sector and stationary fuel combustion from the industry and energy sectors. In urban areas, NO_x

gives the atmosphere a yellow-brown cast. Nitrogen oxides also play a central role in photochemical smog and oxidant (ozone) formation.

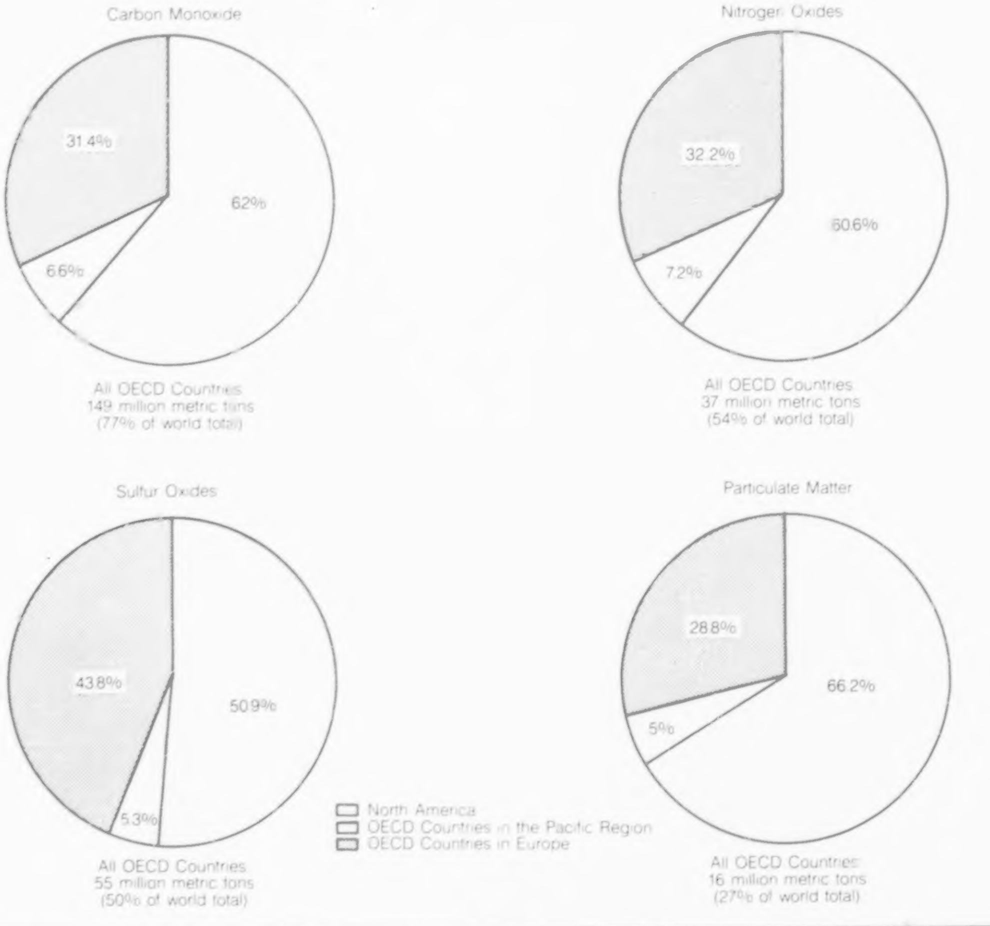
Emission trends. From 1970–79 in the OECD countries, NO_x emissions from stationary sources remained relatively stable but increased in the transportation sector. However, for 1979–84, there has been an overall decrease (or stabilization) of NO_x emissions in Japan, North America, and most of OECD Europe (except Southern Europe). In the Federal Republic of Germany, NO_x emissions have increased by 55 percent in the past two decades. (See Figure 10.2.) The distribution of NO_x emissions in major OECD regions is given in Figure 10.3, and the U.S. emissions estimates appear in Table 10.6.

Overall, emission trends reflect the increased volume of road traffic since the 1960s as well as the number of diesel cars. In the United States, however, the rate of increase in emissions has been dropping because of the controls placed on vehicle emissions since the mid-1970s: NO_x increased 7 percent from 1970–83, with a 2 percent increase since 1975.

Only in Japan has there been a significant decrease in total NO_x: emission levels dropped by more than 90 percent, despite a dramatic increase over the past 20 years in the number of vehicles, especially passenger cars. This improvement is due to the fact that in the mid-1960s, Japan began to impose strong NO_x emission controls on both mobile and stationary sources.

Air quality trends. Generally, trends in NO_2 air quality patterns are similar to estimated NO_x emissions. For selected cities in the OECD network, ambient NO_2 levels remained relatively stable from 1975–79, except in London, where they actually decreased. Annual average concentrations increased in the United States from 1975–79 and then began decreasing; for 1979–83 NO_x concentrations decreased by 15 percent.

Figure 10.3 Emissions of Air Pollutants in Selected OECD Countries, 1980



Source: Adapted from Organization for Economic Co-operation and Development (OECD), 1935. Reference 1. Compendium Table 2.1A

Table 10.4 Trends in Annual Averages of Sulfur Dioxide and Suspended Particulate Matter (SPM) at GEMS[a] sites, 1973–80

Site	No. of sites	Percentage of sites showing different trends		
		Downward[b]	Stationary	Upward[c]
Sulfur Dioxide				
All sites	63	54	30	16
City center	34	56	26	18
Suburban	29	52	34	14
Commercial	23	61	17	22
Industrial	20	55	30	15
Residential	20	45	45	10
Suspended Particulate Matter				
All sites	62	43	47	10
City center	34	47	47	6
Suburban	28	39	46	15
Commercial	21	38	52	10
Industrial	20	50	40	10
Residential	21	42	48	10

Notes:
a. Global Environmental Monitoring System.
b. Downward is defined as a change of at least -3 percent.
c. Upward is defined as a change of +3 percent or more.
Source: World Health Organization (WHO), *Urban Air Pollution 1973-80* (United Nations Environment Program (UNEP/WHO, Geneva, 1984), p. 48.

Carbon Monoxide (CO)

Sources. In most industrialized countries, local sources in urban areas are responsible for the relatively high ambient concentrations of carbon monoxide. The transportation sector contributes about 90 percent of all manmade CO emissions.

Emission trends. According to OECD data (24), total emissions decreased significantly from 1970–79 in North America and Japan, with mixed trends in Western Europe. An overall decline—or at least a stabilization—of CO emissions has continued since 1979 in the OECD countries. Figure 10.3 shows the distribution of CO emissions in 1980 from the major OECD regions; U.S. emissions from 1940–1983 are shown in Table 10.6.

Despite a continuing increase in vehicular traffic, CO emissions have decreased since 1975, mainly as a result of the auto emissions control programs, especially in Japan and the United States. In Japan, emission levels decreased by more than 50 percent between 1971 and 1981. In the United States, the trends show CO emissions decreasing by 31 percent from 1970–83; from 1975–83 the levels decreased by 16 percent.

Air quality trends. For OECD countries there has been a general decline or stabilization in the ambient level of carbon monoxide from 1975–79. The annual average concentrations in Japan peaked around 1960 and have been steadily declining since then. Between 1975 and 1983, the trend in the United States indicates a decrease of 33 percent, with little change from 1982–83 (25).

PROBLEMS REMAIN

In spite of generally positive trends in OECD countries, many problems remain (26):

- National ambient air quality standards as well as recommended concentration limits set by the WHO are still exceeded in many densely populated or industrial areas.
- Many cities in developing countries, where pollution control programs are not well developed, are experiencing an overall decline in air quality as industrialization grows.
- The health and environmental impacts of NO_x may be greater than initially anticipated, particularly as they relate to the formation of ozone and their role in forest decline.
- The control of fine particulate matter has not yet been satisfactorily accomplished.
- Despite control efforts, ozone in the lower atmosphere has continued to increase, exacerbating related health and ecological effects.
- Urban photochemical smog is emerging as a large-scale problem of international significance.

In addition to the problems related to these traditional pollutants, concerns are emerging about the emissions of "new pollutants." Of special concern is the increased

Table 10.5 Trends in Sulphur Dioxide Concentrations in Urban Areas of Selected OECD[a] Countries, 1975–83[b]

	Category[d]	1975 (μg/m³)	SO_2 Index (base 100 in 1975)[c]					
			1975	1979	1980	1981	1982	1983
Canada								
Montreal	A	61	100	74	80	64	61	X
United States								
New York	A	43.1	100	82	83	83	82	77
Detroit	B	38.1	100	83	68	77	76	67
Japan								
Tokyo	A	60.2	100	81	80	71	70	49
Kawasaki	B	59.6	100	63	59	58	61	46
Australia								
Sydney	A	39.0	100	103	97	93	81	X
Newcastle	B	33.0	100	58	88	84	X	X
Belgium								
Brussels	A	99.0	100	73	63	53	45	X
Liège	C	85.0	100	80	92	74	74	X
France								
Paris	A	115.0	100	90	77	62	59	53
Rouen	B	63.0	100	132	111	78	76	65
Germany								
Berlin	A	95.0	100	111	96	81	86	71
Ruhr Area	B	161.0	100	80	60	X	X	X
Italy								
Rome	A	62.0	100	162	121	140	143	X
Milan	B	244.0	100	111	76	73	52	X
Luxembourg	C	61.0	100	57	61	61	55	34
Netherlands								
Amsterdam	A	34.0	100	100	74	76	62	59
Rotterdam/Rijn	B	52.0	100	92	75	81	69	71
Norway								
Oslo	A	48.0	100	88	75	65	42	35
Portugal								
Barreiro/Seixal	B	98.1	100	88	125	116	65	63
Sweden								
Gothenburg	A	41.0	100	106	59	80	46	45
United Kingdom								
London	A	123.0	100	80	82	67	61	49
Newcastle	B	115.0	100	81	80	57	51	35

X = not available
Notes:
a. Organization for Economic Co-operation and Development.
b. Methods of measurement are not strictly comparable among cities.
c. Annual average daily concentrations are given here as examples of general trends that have been confirmed in national reports and other sources.
d. Categories of cities: A: a city in which a notable portion (5-10 percent) of the national population is concentrated. B: industrial city in which a significant number of inhabitants are considered to have been exposed to a comparatively high level of pollutants in 1980. C: others, country network for Luxembourg.
Source: Organization for Economic Co-operation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985), Table 2.2A.

Table 10.6 Summary of National Emission Estimates in the United States, 1940–83

Year	Particulates (PM)[a]	Sulfur Oxides (SO_x)[a]	Nitrogen Oxides (NO_x)[a]	Volatile Organics (VOC)[a]	Carbon Monoxide (CO)[a]	Lead (Pb)[b]
1940	22.4	18.0	6.7	17.7	79.4	X
1950	24.2	20.3	9.3	20.3	84.8	X
1960	20.9	20.0	12.8	23.3	87.5	X
1970	18.0	28.2	18.1	27.0	98.3	20.0
1971	16.7	26.8	18.5	26.3	96.3	22.0
1972	15.0	27.4	19.7	26.3	93.8	23.0
1973	13.9	28.7	20.2	25.7	89.5	202.7
1974	12.2	27.0	19.6	24.1	84.6	162.1
1975	10.3	25.6	19.1	22.7	80.5	147.0
1976	9.6	26.2	20.3	23.8	85.3	153.1
1977	9.0	26.3	20.9	23.6	81.1	141.2
1978	8.9	24.5	21.0	24.2	80.6	127.9
1979	8.8	24.5	21.1	23.5	77.4	108.7
1980	8.3	23.2	20.3	22.3	75.0	70.6
1981	7.7	22.3	20.5	21.0	72.3	55.9
1982	6.8	21.3	19.6	19.4	66.1	54.4
1983	6.9	20.8	19.4	19.9	67.6	46.9
Percent						
Change 1940–1983	–69	+16	+190	+12	–15	X
Change 1970–1983	–62	–26	+7	–26	–31	–77
Change 1975–1983	–33	–19	+2	–12	–16	–68

X = not available

Notes:

a. Unit of measurement is teragrams/year (10^6 metric tons/year)

b. Unit of measurement is gigagrams/year (10^3 metric tons/year)

Source: U.S. Environmental Protection Agency (EPA), 1984. Reference 6.

number of unconventional trace pollutants in the atmosphere, such as toxic metals, fibers, and organic compounds. They may cause cancer, genetic changes, and birth deformities as well as engendering adverse ecological effects. In general, these substances are not routinely monitored and emissions are not well documented. More research and monitoring are needed in order to determine their levels in ambient air and their potential effects on human health.

ACID DEPOSITION

Acid deposition is a major air quality issue in Europe and North America (27,28,29,30,31,32,33,34), and it may emerge as a significant problem in Asia. Many environmental effects have been attributed to "acid rain," including damage to lakes, streams, groundwater, forests, agriculture, buildings, statues, and human health.

"Acid rain" is a popular label for the complex scientific phenomena associated with atmospheric deposition. It is misleading, however, because acidic substances are not only deposited in rain, snow, fog, and dew, but they also fall from the atmosphere as dry particles.

The acid rain issue has undergone several significant changes in the last few years:

- Scientific and policy concerns have expanded beyond the threat of acidification of aquatic ecosystems. Observed changes in forests, in particular, have received increased attention.
- Although acid deposition is still seen as the primary atmospheric agent damaging aquatic ecosystems, many other air pollutants may also play a role in forest declines and materials damage.
- The geographic area now perceived as threatened by acid rain and the other air pollutants associated with atmospheric deposition has expanded far beyond Scandinavia and northeastern North America.

Because the emerging issue of multiple pollutants and forest decline is the subject of Chapter 12, this section focuses on the acidic component of atmospheric deposition and its relationship to aquatic ecosystems and the built environment.

Transport of Atmospheric Pollutants

The atmosphere transports many air pollutants hundreds of kilometers before returning them to the earth's surface. During this long-distance transport, the atmosphere acts as a complex chemical reactor transforming the pollutants as they interact with other substances, moisture, and solar energy. Under the right conditions, emissions of sulfur dioxide and nitrogen oxides are transformed chemically during transport into sulfuric and nitric acids. In Northern Europe and eastern North America, about two thirds of the total atmospheric acidity is due to sulfur and one third to nitrogen (35). The ratio varies considerably with season and region, and in some areas, such as the western United States, it can be closer to 1:1.

Acid deposition takes both wet and dry forms. Typically, the dry forms (gases and particles) are found nearer their sources, and wet deposition occurs at longer distances (36). Estimates of dry deposition are uncertain because there is no satisfactory technique for measuring it directly. Nevertheless, the available data suggest that in

Table 10.7 Trends in Concentrations of Suspended Particulate Matter in Urban Areas of Selected OECD Countries[a]

	Category[c]	1975 (µg/m³)	Index, base 100 in 1975[b]					
			1975	1979	1980	1981	1982	1983
Canada								
Montreal	A	103.0	100	69	76	62	53	X
United States								
New York	A	50.4	100	99	102	97	89	86
Chicago	B	70.9	100	103	99	91	77	78
Japan								
Tokyo	A	78.4	100	60	61	65	65	61
Australia								
Sydney	A	112.0	100	72	78	X	65	68
Belgium								
Brussels	A	32.0	100	69	59	63	50	X
Antwerp	B	30.0	100	83	43	60	47	X
France								
Paris	A	57.0	100	105	89	88	82	81
Nantes	C	36.0	100	56	39	42	31	44
Germany								
Ruhr Area	B	114.0	100	81	74	70	79	X
Luxembourg	C	37.0	100	57	46	46	41	27
Netherlands								
Amsterdam	A	70.0	100	106	99	97	90	93
Rotterdam/Rijn	B	70.0	100	103	90	97	81	80
Norway								
Oslo	A	32.0	100	61	84	103	81	84
Portugal								
Lisbon	A	162.7	100	X	101	101	101	98
United Kingdom								
London	A	36.0	100	64	53	58	50	61
Stoke-on-Trent	B	54.0	100	72	56	67	46	54

X = not available

Notes:

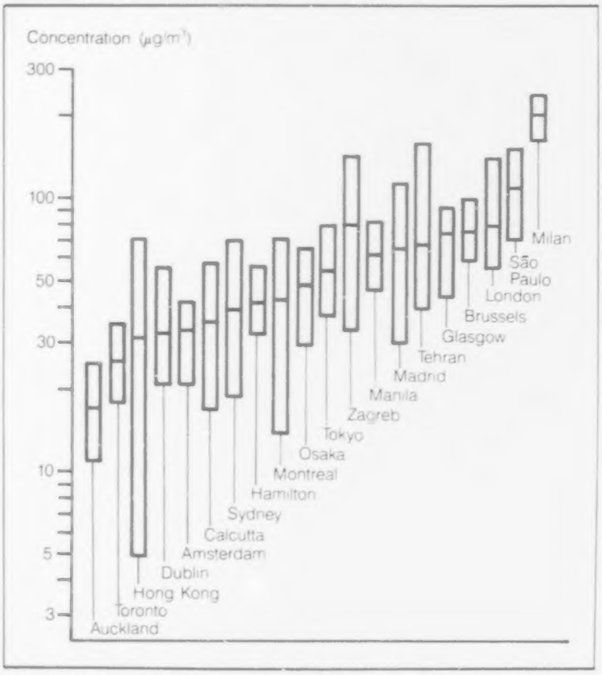
a. Methods of measurement are not strictly comparable among cities.

b. Categories of cities: A: a city in which a notable portion (5-10%) of the national population is concentrated; B: industrial city in which a significant number of inhabitants are considered to be exposed to a comparatively high level of pollutants in 1980; C: others; country network for Luxembourg.

c. Annual average daily concentrations are given here as examples to illustrate general trends which are confirmed in national reports and other sources.

Source: Organization of Economic Cooperation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985), Table 2.2C.

Figure 10.4 SO_2 in Cities of the GEMS Monitoring Network, 1976–80



Note: Shading indicates range of annual averages at individual sites. Lines within shaded areas show the composite average for each city.
Source: B. Bennett *et al.*, 1985, Reference 4.

some regions—with concentrations of heavy industry, power plants, and traffic—up to about 50 percent of the acid deposited may be dry particles (37). In dry areas of the western United States, the dry to wet deposition ratio may approach 15:1 (38).

Gaseous sulfur can remain suspended in the atmosphere from hours to weeks before being deposited (39). Time allows the winds to carry sulfur and its end products long distances from their origin; a small fraction of the sulfur deposited in Europe even originates in North America (40). In Europe and eastern North America, studies show that on average roughly one third of deposited sulfur compounds come from sources over 500 kilometers away, one third from sources 200–500 kilometers away, and the remaining one third from sources within 200 kilometers of the deposition site (41).

The exchange of air pollution between nations can be enormous in both scale and complexity. The Federal Republic of Germany (FRG) is a good example. As a major SO_2 emitter in Central Europe, the FRG is surrounded by other pollution sources, so it sends pollution in and receives pollution from all directions. The Federal Republic estimates that it is responsible for 124,000 metric tons of sulfur deposited in upwind France each year. France reciprocates by sending an estimated 167,000 metric tons across the FRG border where it contributes to a grand total of 760,000 metric tons dumped annually on the Federal Republic (42). This exchange shows the complexity of pollution patterns, even though the prevailing winds in Europe are generally in a northeasterly direction. It is clear that any serious attempt to reduce acid deposition over a broad region like Western Europe and Scandinavia will require concerted multinational action.

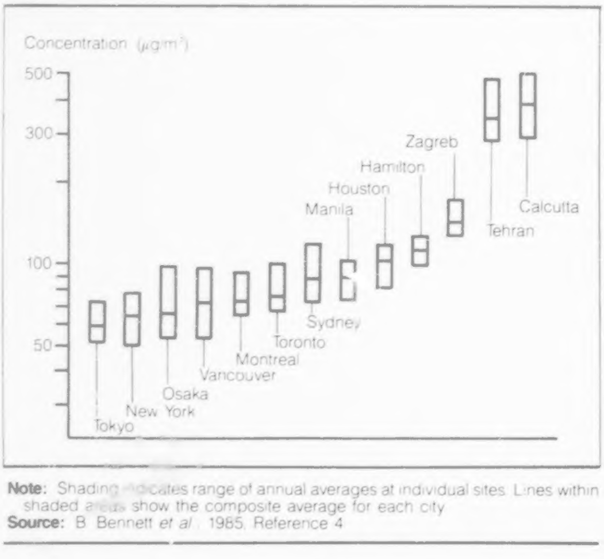
Deposition

The highest levels of acid deposition are in the regions with the highest levels of man-made sulfur and nitrogen emissions. On a global basis, probably 50 percent of the atmospheric sulfur is from natural sources. But in industrialized regions, like Europe and eastern North America, over 90 percent of the deposited sulfur is from man-made emissions (43).

Precipitation is naturally acidic, with a global background pH of around 5.0 (44). This background acidity is from atmospheric CO_2, natural sulfur and nitrogen compounds, and organic acids. At some remote sites, pH values even lower than 5.0 are found, but the amount of acid deposited is small; it usually includes significant contributions from weak organic acids (like acetic and formic) rather than the strong acids associated with fossil fuel emissions (45). Figure 10.6 shows that a major industrialized region like eastern North America experiences precipitation with very low pH values (as much as 6 times more "enriched" in hydrogen ions) compared to remote regions (46).

The pattern of the annual average pH of precipitation for North America is shown in Figure 10.7. Large areas in and downwind from major emission zones experience precipitation that averages pH 4.2–4.5. Rainfall can be as acidic as pH 3 (vinegar) or even worse; one rainstorm that drenched Wheeling, West Virginia, in the United States, had a pH of 1.5 (battery acid has a pH of 1) (47).

Figure 10.5 Suspended Particulate Matter in Cities of the GEMS Air Monitoring Network, 1976–80



Note: Shading indicates range of annual averages at individual sites. Lines within shaded areas show the composite average for each city.
Source: B. Bennett *et al.*, 1985, Reference 4.

An analysis of ice cores from Greenland spanning more than a century—from 1869–1984—indicates that anthropogenic sulfate has dominated deposition since the early 20th Century, and anthropogenic nitrate has played a major role since about 1960 (48). These trends roughly parallel man-made emissions over that period.

More spatially and temporally detailed analyses of trends over recent decades are possible using monitoring data available for up to 120 Western European sites, which comprise the European Air Chemistry Network (49). Sulfate deposition has increased an average of about 2.5 percent per annum from 1955–75 at 12 sites in Scandinavia (50). Since 1975, however, sulfate deposition has either decreased or remained constant over most of the network.

In contrast, nitrate concentrations have generally increased since the 1960s. For the 12 sites in Scandinavia, increases in nitrate averaged about 6 percent per annum over the period 1960–80 (51). These overall deposition trends roughly follow the pattern of nitrogen emissions for Western Europe during the period of monitoring.

North America has not kept pace with monitoring efforts in Western Europe. Only one site in the United States has a record extending back over 20 years, Hubbard Brook, New Hampshire (52). The data from this northeastern site showed no marked trend in acidity but a general decrease in sulfate and a compensating increase in nitrate from 1964–77. The trends in sulfate and nitrate deposition roughly correspond to sulfur and nitrogen emissions.

Since about 1980, when more extensive monitoring began, average annual patterns for wet deposition in the United States have shown few significant changes, reflecting the fact that emissions have remained relatively constant (53). The area receiving in excess of 20 kilograms per hectare per year of wet sulfate has remained similar from year to year (54).

Outside Western Europe and North America, data on acid deposition are sparse. Some monitoring of precipitation chemistry in Japan reveals acidities of around pH 4.2 in the Kanto region (55). Observations from some Japanese sites with long-term records show increasing acidity during the mid- to late-1960s. China has also experienced acid deposition in both rural and urban areas (56). Precipitation monitoring stations have recorded a pH of 4 or below near Chungking and other urban areas, values which are probably related to the large quantities of coal burned in China.

ACIDIFICATION OF AQUATIC ECOSYSTEMS

Acidification of surface waters has occurred in Western Europe and eastern North America, although it has also affected parts of the western United States (57). Emission levels and geology suggest that acidified waters could exist in other industrialized regions. Surface waters that are below about pH 5 and that are poorly buffered generally have relatively unproductive fisheries or are incapable of supporting any fish populations at all.

Many factors can affect the pH of surface waters—bedrock composition, hydrology, surrounding vegetation, bog-lake interactions, forest-soil processes, and land use practices as well as the atmospheric deposition of acids. In regions such as southern Scandinavia that generally have poorly buffered waters and receive high levels of atmospheric deposition, acid rain is usually cited as the major cause of freshwater acidification.

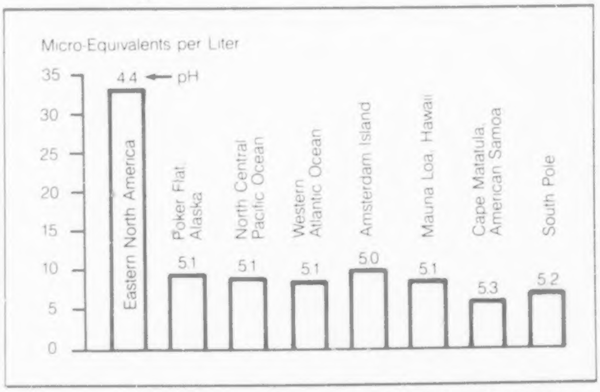
Sweden estimates that of its 90,000 or more lakes, 4,000 are highly acidified, with a pH below 5 (58). In addition, approximately 18,000 more have experienced some acidification, and another 20,000 are at risk if current levels of deposition continue. Sweden also has about 90,000 kilometers of acidified streams. Damage to fish stocks ranges from temporary disruption of life cycles to outright loss of whole populations in the acidified waters of southern and western Sweden (59). Some lakes on Sweden's west coast have become considerably more acidic since the 1930s, dropping as much as 100-fold from pH 6 to pH 4.

In southern Norway, lakes with a total surface area of 13,000 square kilometers support no fish, and stocks have been depleted over an additional 20,000 square kilometers (60). Fish populations in Norway's southern lakes have declined markedly, with 74 percent of the brown trout and 53 percent of the perch stock disappearing since the 1950s. Until 1978, Atlantic salmon had disappeared from southern Norway due to the acidification of key spawning sites (61).

Some small headwater streams and lakes in poorly buffered regions of the Federal Republic of Germany are reportedly acidified (62), and in the German Democratic Republic pH values as low as 3.9 have been documented in some areas. Likewise, Scotland has some acidified lakes in the Galloway region, where the soils are thin and are underlain by granite (63). In the Netherlands, aquatic effects have only recently been recognized, but initial observations suggest that up to 70 percent of the most sensitive lakes have been acidified (64).

Acidified lakes have also been identified in North America. More than 300 lakes in Ontario, Canada are

Figure 10.6 Hydrogen Ion Concentration in the Northeastern United States, as Compared to Relatively Remote Areas



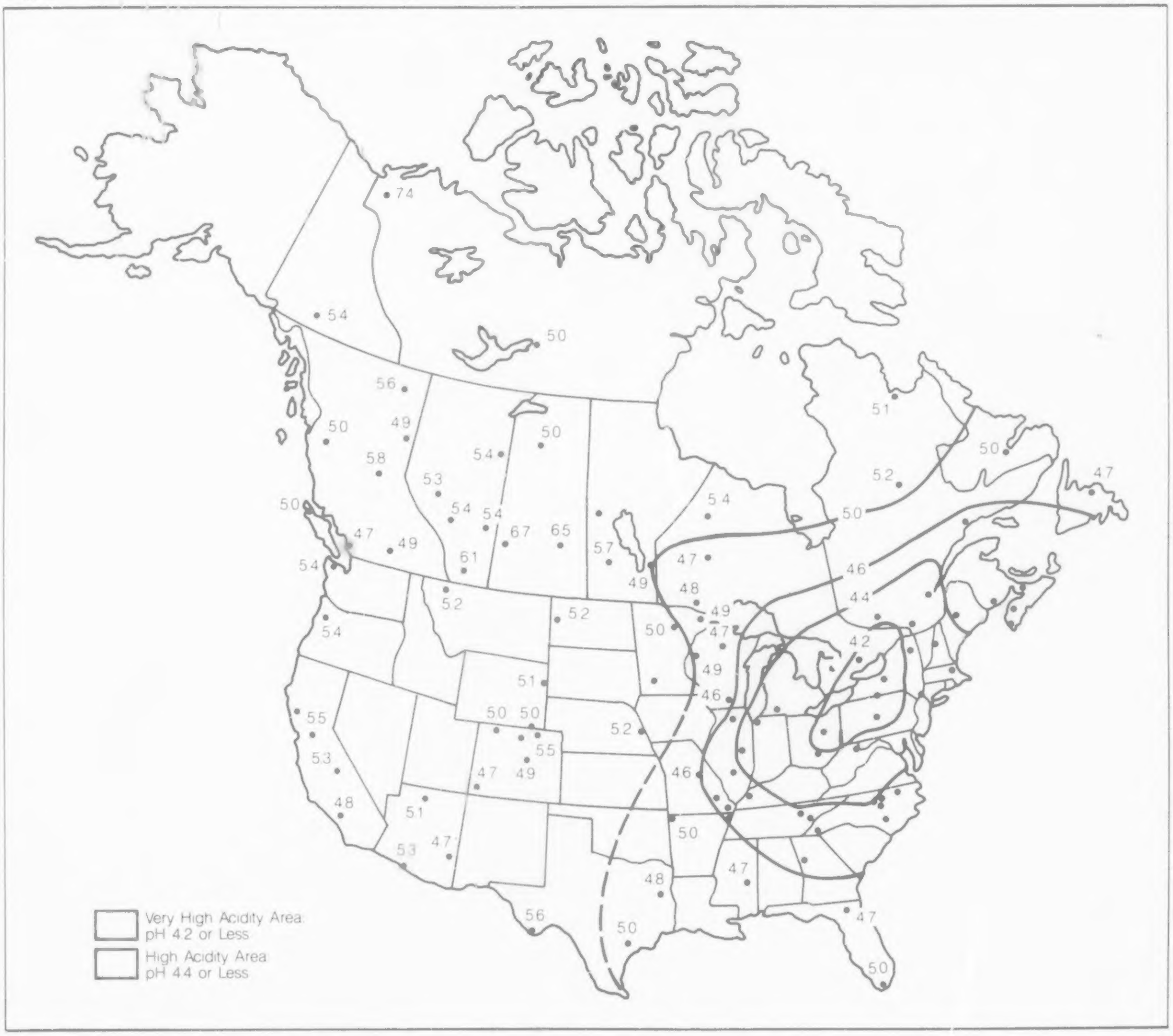
Source: J.M. Miller, "Acid Rain," *Weatherwise*, Vol. 37, No. 5, p. 239 (1984).

estimated to have a pH value below 5 with an additional 48,000 lakes (about 3 percent of the total) listed as being sensitive to acid deposition (65). Nine rivers in Nova Scotia have pH values below 4.7 and no longer support salmon or trout reproduction (66).

The most extensive survey of surface water chemistry ever conducted is currently underway as part of the U.S. National Acid Precipitation Assessment Program. Initial results from the U.S. National Surface Water Survey covering a statistically representative sampling of lakes in the eastern United States indicate that 10 percent of the lakes in the highly sensitive Adirondack region have pH values below 5 (67).

A similar high percentage was found in the Upper Peninsula of Michigan, but in other sensitive regions of the eastern United States, the average number of lakes below pH 5 was about 5 percent. In northern Florida, 12 percent of the lakes showed a pH below 5, which may

Figure 10.7 Distribution of Acidity of Rain Over the United States and Canada, 1982


7.4
5.4
5.0
5.6
5.0
4.9
5.0
5.8
5.4
5.3
5.1
5.0
4.7
5.2
5.0
4.7
4.9
5.4
5.4
6.7
6.5
5.7
5.4
6.1
4.7
4.8
4.9
4.6
4.4
5.2
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5.0
4.2
5.1
4.9
4.6
5.5
5.0
5.0
5.5
5.2
5.3
4.7
4.9
4.6
4.8
5.1
4.7
5.3
5.0
4.8
4.7
5.6
5.0
4.7
5.0
Very High Acidity Area pH 4.2 or Less
High Acidity Area pH 4.4 or Less

Notes:
a. Map refers to wet deposition only. The pattern for dry deposition is likely to be similar.
b. Shaded areas indicate where high acidity (lower range of pH) occurs.
c. Dots are stations of a consortium of governmental and other institutions for acid-rain monitoring.
d. Numbers are pH readings at sample sites.
e. Lines show areas with approximately equal pH values.
Source: National Acid Precipitation Assessment Program (NAPAP), 1984. Reference 32.

be due to naturally occurring organic acids draining from major swamps in the region.

The U.S. National Surface Water Survey also found that a large proportion of the eastern lakes in sensitive regions had low acid neutralizing capacities (ANC). For the Adirondacks, 31 percent of the lakes had an ANC less than 40 microequivalents per liter and 70 percent had an ANC of less than 200 microequivalents per liter (200 is often considered the threshold of vulnerability to acid deposition). The ANCs of about 60 percent of the lakes in the other sensitive regions of the eastern United States are estimated at below 200 microequivalents per liter, as are the ANCs of 41 percent of the lakes in the southeast region located in sensitive areas (68).

Cause and Effect Relationships

The relationship between acid deposition and surface water chemistry is complex. Most of the precipitation that eventually enters a lake has fallen on vegetation and run over or through soil before reaching the lake. During this journey, the acidity of the runoff can be modified by a factor of ten or more (i.e., more than 1 pH unit) (69). One result of this phenomenon is that although generally sensitive (low ANC) regions can be defined, the fate of any given body of water within them is determined by specific local factors.

Acidification causes many profound changes in aquatic ecosystems, affecting all trophic levels. The impact on fish is the most visible and thoroughly studied aspect of the problem. Fish reproduction and health are impaired not only by the toxicity of hydrogen ions but also by the toxicity of the metals mobilized by the increased acidity.

Aluminum (Al) poisoning is a major factor in reported fisheries declines and losses (70). As pH decreases, the toxicity of aluminum increases. At about pH 5, aluminum is most lethal to fish because it precipitates in their gills as aluminum hydroxide, reducing the oxygen content in the blood and causing salt imbalances in the fish. The problem is most acute where the organic content in the water is low, as is true of many acid-sensitive lakes. In naturally acidic "brown water" lakes, fish can tolerate a lower pH because the high organic content fixes or buffers the aluminum, making it less toxic (71).

Episodic fish kills observed in Europe and North America have usually been accompanied by acid "pulses" (72). These pulses of acidity can be caused by precipitation with very low pH values or by the rapid melting of snow during spring thaws. In either case, the volume and rapidity of the pulse can overwhelm the catchment's ability to neutralize or absorb the acid input so that the depressed pH values generate elevated levels of toxic metals. When the acid pulse is from spring snowmelt, it often occurs at the most vulnerable time in fish life cycles. Snow normally contains more nitrate than do summer rains, so the spring shock can exceed a system's ability to absorb nitrogen. In this way, nitrogen deposition can be more important in some fish kills than is suggested by its relative contribution to total acidity.

DAMAGE TO THE BUILT ENVIRONMENT

Since the mid-19th Century, air pollution has been suspected of accelerating the degradation and corrosion of many types of materials, both natural and man-made. The most susceptible buildings, monuments, memorials, statues, cultural objects, and historical artifacts are located primarily in urban areas, where they are subjected to a host of pollutants. Damage from atmospheric deposition includes corrosion of metals, erosion and discoloration of paints, and deterioration of building stone (73).

Of course, materials that are exposed to the air are regularly subject to wind and solar radiation and a wide variety of other natural stresses, but structural deterioration is accelerated by pollution. In most cases the combined or additive effects of two or more agents causes more significant damage than any single pollutant (74,75,76).

The primary pollutants related to materials damage include sulfur dioxide, nitrogen oxides, ozone, and particulate matter. Because of its widespread distribution, SO_2 is considered the most significant for materials damage (77). The extent of damage to materials from acid deposition, as opposed to the other variables, is not known, and it is difficult to assess the relative contribution of dry-deposited versus wet-deposited substances.

Although the threat to cultural properties from pollution has been demonstrated in Europe, examples from the United States are not as convincing. In Europe, the number of intricately carved architectural surfaces and historical properties is much greater; the times of exposure are longer (centuries versus decades); the stone is often of poor quality; and the pollution levels are higher (78).

Overall, there has been a significant increase in damage to buildings and structures by air pollution in Europe, particularly since the 1950s, with the rapid growth of motor vehicle traffic (79). This trend in Europe coincides with the pattern of increasing levels of emissions and elevated concentrations of some air pollutants. Of primary concern is the extensive damage to stained glass windows, historically valuable natural stone buildings, and bronze memorials. (See Table 10.8.)

Conclusion

The acid deposition issue is going through the transition from scientific pioneering to in-depth analysis of complex environmental phenomena. With the massive international research efforts now underway, the science of acid deposition is maturing. Indeed, more research was performed from 1982–86 than during the previous 20 years. New information means that policymakers now have a better understanding of the problems and can institute more effective controls, but there are no quick or easy solutions.

POTENTIAL CHANGES IN STRATOSPHERIC OZONE

Ozone (O_3), a variant of oxygen (O_2), is present in minute amounts in the atmosphere. Ozone concentrations vary

Table 10.8 Air Pollution Damage to Materials

Material	Type of Damage	Other Principal Air Pollutants	Other Environmental Factors	Measurement Methods	Mitigation Measures
Metals	Corrosion, tarnishing	Sulfur oxides and other acid gases	Moisture, air, salt, particulate matter	Weight loss after removal of corrosion products, reduced physical strength, change in surface characteristics	Surface plating or coating, replacement with corrosion-resistant material, removal to controlled environment
Building Stone	Surface erosion, soiling, black crust formation	Sulfur oxides and other acid gases	Mechanical erosion, particulate matter, moisture, temperature fluctuations, salt, vibration, CO_2, microorganisms	Weight loss of sample, surface reflectivity, measurement of dimensional changes, chemical analysis	Cleaning, impregnation with resins, removal to controlled environment
Ceramics and Glass	Surface erosion, surface crust formation	Acid gases, especially fluoride-containing gases	Moisture	Loss in surface reflectivity and light transmission, change in thickness, chemical analysis	Protective coatings, replacement with more resistant material, removal to controlled environment
Paints and Organic Coatings	Surface erosion, discoloration, soiling	Sulfur oxides, hydrogen sulfide	Moisture, sunlight, ozone, particulate matter, mechanical erosion, microorganisms	Weight loss of exposed painted panels, surface reflectivity, thickness loss	Repainting, replacement with more resistant material
Paper	Embrittlement, discoloration	Sulfur oxides	Moisture, physical wear, acidic materials introduced in manufacture	Decreased folding endurance, pH change, molecular weight change, tensile strength	Synthetic coatings, storing, removal to controlled environment, deacidification, encapsulation, impregnation with organic polymers
Photographic Materials	Microblemishes	Sulfur oxides	Particulate matter, moisture	Visual and microscopic examination	Removal to controlled environment
Textiles	Reduced tensile strength, soiling	Sulfur and nitrogen oxides	Particulate matter, moisture, light, physical wear, washing	Reduced tensile strength, chemical analysis (e.g., molecular weight), surface reflectivity	Replacement with substitute materials, impregnation with polymers
Textile Dyes	Fading, color change	Nitrogen oxides	Ozone, light, temperature	Reflectance and color value measurements	Replacement with substitute materials, removal to controlled environment
Leather	Weakening, powdered surface	Sulfur oxides	Physical wear, residual acids introduced in manufacture	Loss in tensile strength, chemical analysis	Removal to a controlled atmosphere, consolidation with polymers, or replacement
Rubber	Cracking	Ozones	Ozone, sunlight, physical wear	Loss in elasticity and strength, measurement of crack frequency and depth	Addition of antioxidants to formulation, replacement with more resistant materials

Source: J.E. Yocom and N.S. Baer, "Effects on Materials," in *The Acidic Deposition Phenomenon and its Effects*, Vol. 2, Critical Assessment Review Papers (U.S. Environmental Protection Agency, draft, Washington, D.C., 1983), pp. 7-1 to 7-49.

with altitude, but they are highest in the stratosphere (20–25 kilometers above the earth's surface). (See Figure 10.8.) Ozone in the troposphere, closest to the earth's surface, is a pollutant known to damage plants and to affect human health as well. However, stratospheric ozone plays a crucial role in shielding the earth's surface against ultraviolet radiation (UV) by absorbing wavelengths harmful to the health of people, plants, and animals.

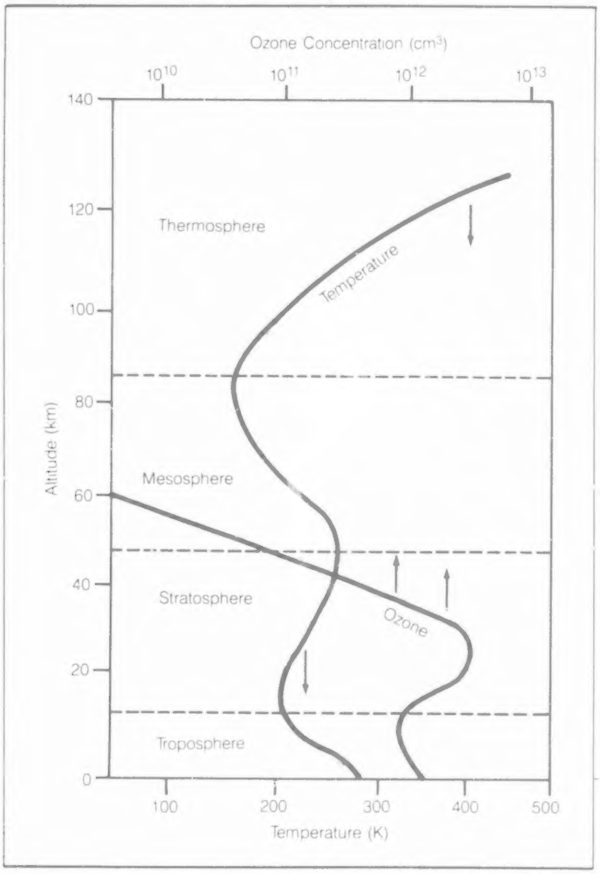
The concentrations of ozone at different altitudes are also critical to the radiative and meteorological processes that determine climate. The absorption of infrared radiation by ozone provides the main heat source for the stratosphere. Changes in stratospheric ozone would affect heating rates, air movements, and the downward emission of infrared radiation. Ozone in the lower stratosphere absorbs heat radiated from the earth; changes in its concentration would affect surface temperatures due to the greenhouse phenomenon. (See "Focus On: The Greenhouse Effect," below.) Changes in atmospheric temperatures could also affect water vapor concentrations thought to be important in climate formation (80,81).

Ozone concentrations are affected by catalytic reactions between the various forms of oxygen and nitrogen, chlorine, and hydrogen oxides. Small amounts (parts per billion) of these catalytic oxides control the actual amount of ozone (82). Human activities are changing the concentrations of these trace gases, and the changes, in turn, are expected to affect the concentration of ozone. A reduction in ozone would allow more UV to reach the earth's surface, and it could result in a range of consequences that have received only modest study (83).

The principal known effect of increased UV radiation on human health is an increase in non-melanoma skin cancers. The possibility of an increase in the rarer, frequently fatal, melanoma form of skin cancer is controversial (84). Other potential effects include suppression of human immunological systems (through effects on elements of the immune system in the skin or the formation of tumor antigens), damage to plants and animals (particularly some economically important species of cattle), and accelerated degradation of polymers. (See Table 10.9.)

The major source of concern to scientists has been a group of chemicals known as chlorofluorocarbons (CFCs), highly stable chemical compounds used in aerosol propellants, refrigeration, foam-blowing, and solvents. The consensus is that continuing emissions of CFCs at current levels would reduce the total amount of ozone by 3–5 percent in about 100 years (their atmospheric lifetime) (85). This small change in the ozone column is the net result of depletion of up to 60 percent of the ozone above 40 kilometers, much smaller reductions at 30 kilometers, and an offsetting increase at lower altitudes. Depletion may also be greater at high latitudes and at different seasons, leading to changes in lateral air movements and to greater increases in UV radiation (86).

Figure 10.8 Temperature Profile and Ozone Distribution in the Atmosphere



Source: National Aeronautics and Space Administration (NASA), 1984. Reference 80.

Modeling calculations of likely changes in stratospheric ozone are sensitive to assumptions about emission rates for CFCs, methane, carbon dioxide, and nitrous oxides. Models show methane and carbon dioxide emissions increasing stratospheric ozone, the former due to direct effects on atmospheric chemistry and the latter through indirect effects on atmospheric temperature and therefore reaction rates (87). Nitrous oxides decrease ozone, while the effect of nitrogen oxides (an airplane exhaust gas) is localized and varies with the altitude of injection. To further complicate matters, the effects are interdependent—the consequences of one chemical vary with the concentration of the others. According to some models, ozone destruction accelerates rapidly when the concentration of chlorine exceeds that of stratospheric odd-nitrogen (NO_x, NO_2, HNO_3^-, etc.).

Growth in CFC emissions seems likely but is difficult to forecast. Projections depend on assumptions about economic growth, the availability of substitutes, and possible new uses (88,89). In the last decade, substantial growth in non-aerosol uses (71 percent) corresponded to nearly comparable reductions in aerosols, but this balance may not continue.

Total CFC production data are not available because no figures have been released by the Soviet Union, Eastern Europe, and the People's Republic of China since 1975 (90). However, most of the world's production of CFCs is reported to the Chemical Manufacturers Association. Its data show increases of almost 8 percent in 1983 and over 7 percent in 1984; even aerosol propellant use increased in those years (91). Consumption in the United States (almost exclusively non-aerosol uses) increased over 10 percent per year in 1983 and 1984. International action to limit future growth of CFCs is currently under consideration. (See "Recent Developments," below.)

FOCUS ON: THE GREENHOUSE EFFECT

The earth's climate is subject to various natural short-term deviations. Recent extreme examples of such anomalies are the drought in much of sub-Saharan Africa and the torrential rains in Ecuador and northwest Peru in late 1982 and early 1983 (92). In addition to these natural anomalies, there is a large and growing body of evidence suggesting that human activities are causing long-term changes in the earth's climate.

One important indicator of whether the climate is stable or is changing is the global mean surface temperature. An analysis of surface temperature data since the middle of the last century shows that both hemispheres experienced a general warming from the late 19th Century until about 1940 and a cooling until the mid-1960s. Since then, the world as a whole appears to have warmed. (See Figure 10.9.) Analyses of these observations suggest that the global mean temperature has increased 0.3°–0.7°C in the past 100 years. (See Box 10.1.)

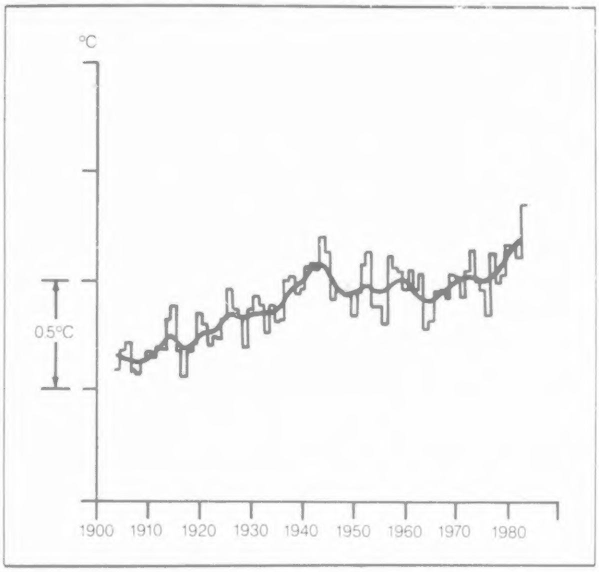
This trend in surface temperature could be due to natural factors alone, but there is reason to believe that it is at least partly due to human influences. Human activities are releasing increasing quantities of certain gases into the atmosphere that are thought to contribute to global warming. These gases are transparent to incoming short-wave radiation from the sun, but they absorb outgoing long-wave radiation. Consequently, increases in their atmospheric concentrations lead to a "greenhouse effect"—a warming of the Earth's surface and the lower atmosphere; for this reason, they are often called "greenhouse gases." Trends in the atmospheric concentrations of the most important of these gases are reviewed below.

Table 10.9 Effects from Ozone Depletion

	Depletion Level		
	2.5%	10%	20%
Human Health Effects			
Non-Melanoma Cases	470,000 per year	1,890,000 per year	3,770,000 per year
Melanoma Cases (Relationship not proven)	15,000 per year	65,000 per year	146,000 per year
Suppression of Immune System	no estimate now possible		
Degradation of Polymer Materials[a]	$\$175 \times 10^6$/yr	$\$2 \times 10^9$/yr	$\$6 \times 10^9$/yr
Eye cancer in Cattle	no estimate now possible		
Effects on Plants	no estimate now possible		
Effects on Aquatic Organisms	no estimate now possible		

Note: a. Rough approximations.
Source: U.S. Environmental Protection Agency (EPA), 1985. Reference 84.

Figure 10.9 Variation with Time of the Global Mean Annual Surface Temperature, 1900–85



Note: Data have been obtained from land and marine temperature records. The filtered curve has been obtained by suppressing variations on time scales of less than ten years.
Source: Bolin, in press, 1986, Reference 93.

Atmospheric Carbon Dioxide Concentrations

The use of fossil fuels and the burning of biomass have increased the amount of carbon dioxide emitted into the atmosphere. Atmospheric concentrations of carbon dioxide have increased about 25 percent over the past 100 years from about 275 parts per million in the late 19th Century to 343 parts per million in 1984 (93). Further, observations at Mauna Loa, Hawaii, have clearly shown an accelerated trend in atmospheric CO_2 concentrations over the last three decades: from about 315 parts per million in 1958 to its current level of 343 parts per million (94). (See Figure 10.10.)

The estimated increase in the global mean temperature in the past 100 years is consistent with the observed increase in CO_2 and other greenhouse gases. Additional increases in CO_2 concentrations are expected to cause further warming. The most advanced experiments with general circulation models of the atmosphere-land-ocean system show that increases in CO_2 and other greenhouse gases, equivalent to a doubled atmospheric CO_2 concentration, would probably increase the global equilibrium surface temperature 1.5°–4.5°C.

Future trends in the atmospheric concentrations of CO_2 depend upon trends in fossil fuel use and emissions from the burning of biomass. At present, about 5 gigatons of carbon are emitted each year into the atmosphere through the combustion of fossil fuels. Although biotic emissions of carbon dioxide as a result of deforestation and land use changes have also contributed to the raised atmospheric carbon dioxide concentration in the past, it is clear that future emissions from biomass sources will be far smaller than those from fossil fuel combustion.

The CO_2 contribution from fossil fuel use will depend upon how energy demand evolves over time. As Chapter 7, "Energy," notes (see especially Figure 7.7), because there is a wide range of possible scenarios for future energy demand, there is a wide range of possible carbon dioxide emission rates. Rapid growth in energy and fossil fuel consumption could lead to a doubling of CO_2 (to over 600 parts per million) by about the year 2040; a low CO_2 emission scenario could postpone such a doubling until after the year 2100 (95).

Trends for Other Greenhouse Gases

Carbon dioxide is not the only atmospheric constituent that is of importance to the heat budget of the atmosphere and, thus, the global temperature.

It has become apparent in the past few years that the combined contribution of other greenhouse gases to global warming and climate change is already about as important as that from CO_2. These gases are accelerating the rate of global warming arising from the greenhouse effect. Atmospheric concentrations of some of them (e.g., methane and certain chlorofluorocarbons) are increasing more rapidly than those for CO_2. The growing recognition of their importance is reflected in the fact that the title and scope of the Villach Conference were changed several months before it took place so that it covered these other greenhouse gases as well as CO_2. (See Box 10.1.)

Methane

Methane is produced by microbes during the breakdown of organic carbon compounds under anaerobic conditions such as those found in waterlogged soils and in the intestines of ruminants. It is also released to the atmosphere when biomass is burned and during the production of coal and natural gas.

In recent years, the analysis of air trapped in glacial ice has made it possible to measure trends in atmospheric methane concentrations over long periods and with considerable accuracy. The methane concentration in Greenland ice containing air ranging from 50–27,000 years old is approximately 0.7 parts per million, which is only about half the present value (96). Methane concentrations began to increase about 300 years ago, but only within the past 20 years has the rapid change taken place (97,98). The atmospheric methane concentration has recently been increasing at a rate of 1–2 percent a year (99,100). There is still considerable uncertainty over the reasons for this increase, but possible causes are an increase in the number of domestic ruminants, more widespread cultivation of rice paddies, and biomass burning.

Chlorofluorocarbons

A recent analysis of the role of chlorinated and/or fluorinated hydrocarbons in the radiative balance of the atmosphere showed that $CFCl_3$ (F11) and CF_2Cl_2 (F12) are

Box 10.1. The Villach Conference

In October 1985, a conference was held at Villach, Austria, on greenhouse gases, climatic change, and associated impacts. The Villach conference was sponsored by UNEP, the World Meteorological Organization, and the International Council of Scientific Unions; it was the second in a series of five-year reviews. At the end of the conference, the following statement was issued outlining the current international consensus (1).

"The Conference reached the following conclusions and recommendations:

- "Many important economic and social decisions are being made today on major irrigation, hydropower, and other water projects; on drought and agricultural land use; on structural designs and coastal engineering projects; and on energy planning, all based on assumptions about climate. Most such decisions assume that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption. . . It is a matter of urgency to refine estimates of future climate conditions to improve these decisions.
- "Climate change and sea level rises due to greenhouse gases are closely linked with other major environmental issues, such as acid deposition and threats to the Earth's ozone shield, mostly due to changes in the composition of the atmosphere by human activity. Reduction of coal and oil use and energy conservation undertaken to reduce acid deposition will also lower concentrations of greenhouse gases; reduction in emissions of chlorofluorocarbons will help protect the ozone layer and will also slow the rate of climate changes.
- "While some warming of climate now appears inevitable due to past actions, the rate and degree of future warming could be profoundly affected by governmental policies on energy conservation, use of fossil fuels, and the emission of some greenhouse gases.

"These conclusions are based on the following consensus of current basic scientific understanding:

- "The amounts of some trace gases in the troposphere, notably carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), chlorofluorocarbons, and ozone, are increasing. . .
- "The role of greenhouse gases other than CO_2 in changing the climate is already about as important as that of CO_2. If present trends continue, atmospheric CO_2 and other greenhouse gases combined would be radiatively equivalent to a doubling of CO_2 from pre-industrial levels possibly as early as the 2030s.
- "The most advanced experiments with general circulation models of the climatic system show increases of the global mean equilibrium surface temperature for a doubling of the atmospheric CO_2 concentration, or the equivalent, of 1.5–4.5°C. . .
- "While other factors such as aerosol concentrations, changes in solar energy input, and changes in vegetation may also influence climate, the greenhouse gases are likely to be the most important cause of climatic changes over the next century.
- "Regional scale changes in climate have not yet been modelled with confidence. However, regional differences from the global averages show that warming may be greater in high latitudes during late autumn and winter than in the tropics, annual mean runoff may increase in high latitudes, and summer dryness may become more frequent over the continents at middle latitude in the Northern Hemisphere. In tropical regions, temperature increases are expected to be smaller than the average global rise, but the effects on ecosystems and humans could have far-reaching consequences. . .
- "It is estimated on the basis of observed changes since the beginning of this century, that global warming of 1.5°–4.5°C would lead to a sea level rise of 20–140 centimeters. A sea level rise in the upper portion of this range would have major direct effects on coastal areas and estuaries. A significant melting of the West Antarctic ice sheet leading to a much larger rise in sea level, although possible, is not expected during the next century.
- "Based on analyses of observations, the estimated increase in global mean temperature during the last 100 years of 0.3°–0.7°C is consistent with the observed increase in CO_2 and other greenhouse gases, although it cannot be ascribed in a scientifically rigorous manner to these factors alone.
- "Based on evidence of effects of past climatic changes, there is little doubt that a future change in climate on the order of magnitude obtained from climate models for a doubling of the atmospheric CO_2 concentration could have profound effects on global ecosystems, agriculture, water resources, and sea ice.

RECOMMENDED ACTIONS

- "Governments and regional intergovernmental organizations should take into account the results of this assessment in their policies on social and economic development, environmental programs, and control of emissions of radiatively active gases.
- "Major uncertainties remain in predicting changes in global and regional precipitation and temperature patterns. Ecosystem responses are also imperfectly known. Nonetheless, the understanding of the greenhouse question is sufficiently developed that scientists and policymakers should begin an active collaboration to explore the effectiveness of alternative policies and adjustments. . .
- "Governments and funding agencies should increase research support and focus efforts on crucial unsolved problems related to greenhouse gases and climate change. . . Special emphasis should be placed on improved modeling of the ocean, cloud-radiation interactions, and land surface processes.
- "Support for the analysis of policy and economic options should be increased by governments and funding agencies. In these assessments, the widest possible range of social responses aimed at preventing or adapting to climate change should be identified, analyzed, and evaluated. . . Some of these analyses should be undertaken in a regional context to link available knowledge with economic decisionmaking and to characterize regional vulnerability and adaptability to climatic change. Candidate regions may include the Amazon Basin, the Indian subcontinent, Europe, the Arctic, the Zambezi Basin, and the North American Great Lakes."

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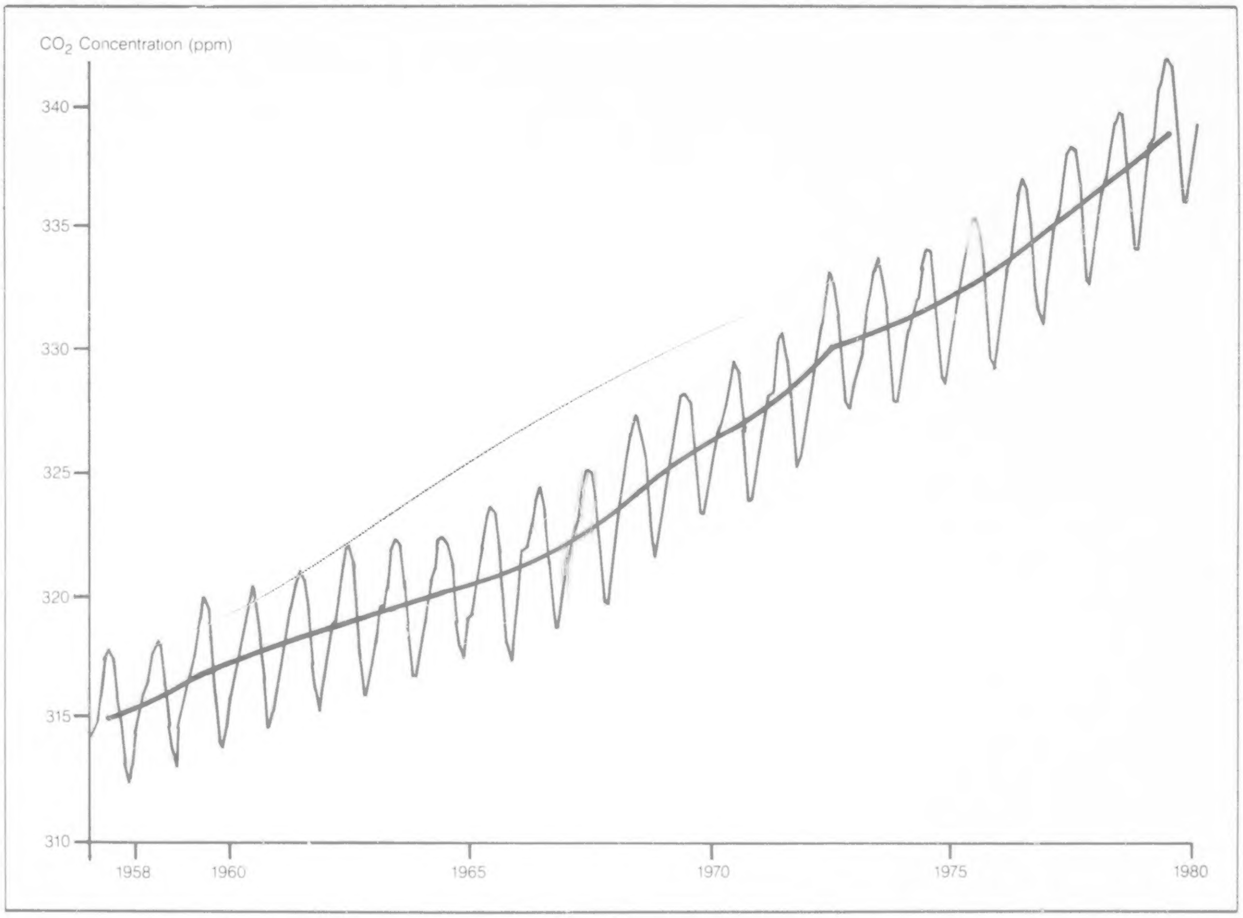
the most important ones (101). At the beginning of 1980, the average concentration of F11 in the lower troposphere was estimated at 168 parts per trillion by volume, increasing at an annual rate of 5.7 percent (102). The F12 concentration was estimated at 285 parts per trillion by volume, with an annual increase of 6 percent (103).

Production of these gases for non-propellant uses has been increasing steadily (see "Potential Changes in Stratospheric Ozone," above), and if it continues to do so, CFCs' contribution to the greenhouse effect will be the second largest (after CO_2) during the first half of the next century.

Figure 10.10 Mean Monthly Concentrations of Atmospheric CO_2 at Mauna Loa, 1958–80



Source: National Research Council, 1983. Reference 120.
Note: The yearly oscillation is explained mainly by the annual cycle of photosynthesis and respiration of plants in the northern hemisphere.

Nitrous Oxide (N_2O)

During the last few years, several studies have shown a steady increase in tropospheric N_2O (104,105,106). This trend appears to be due primarily to rapidly increasing emissions from fertilizer applications and the combustion of biomass and fossil fuels (107).

Anthropogenic N_2O emission rates are expected to increase less rapidly because of changes in fuel consumption trends and limitations on the total amount of land available for cultivation. (See Chapter 7, "Energy.") However, because N_2O has a long atmospheric residence time (about 170 years), concentrations would continue to increase for several decades even if release rates were to remain constant. A 20–25 percent increase in N_2O concentrations by the year 2030 was suggested recently (108,109).

Ozone

Ozone concentrations vary considerably in both space and time as a result of atmospheric motion and chemical reactions. The lifetime of the ozone molecule in the troposphere is only a few weeks, making it difficult to identify long-term global trends in ozone concentrations. Despite these difficulties, it is now accepted that tropospheric ozone concentrations (near the earth's surface) are increasing due to photochemical processes. An increase has taken place at middle and high latitudes of the Northern Hemisphere during the last 2–3 decades: changes of 20–50 percent have been recorded and the present rate of increase seems to be 1–2 percent per year (110). Increases also seem to have occurred in the tropics, particularly in areas of extensive biomass burning.

The increase in ozone in the troposphere has been matched by a decrease in the stratosphere. Because about 90 percent of the ozone is found in the stratosphere, total ozone concentration trends primarily reflect changes at these higher levels. Therefore, overall ozone levels have been decreasing (111).

The Effects of Climate Change

As well as leading to a general global warming of 1.5–4.5°C, a doubling of the atmospheric CO_2 concentration or the equivalent is expected to affect different parts of the world in different ways. Equatorial temperatures are thought likely to increase by about 50–100 percent of the average global warming. At the same time, average annual polar temperatures are likely to rise by two to three times the average global increase (112). There is also some evidence that mid-latitude, mid-continental drying during the summer (113) will occur, posing problems for agriculture in some developed nations. It is not yet possible to assess the regional impacts of the changing climate with any certainty, although many studies have been done on the type of impacts that could occur.

Agriculture tends to be acutely sensitive to climate. For example, in the United States the areas of optimal cereal production are narrowly defined. The western boundary of Corn Belt production is set by moisture requirements, especially by the need for a minimum of 20 inches of annual moisture. The southern boundary is defined by thermal considerations. On average, yields for corn decline 20 percent and 10–15 percent, respectively, with increases in regional temperature of 2°C and reductions in precipitation of 10 percent (114). Other crop yields, such as wheat, are similarly climate sensitive. Thus, U.S. agriculture might be significantly affected by a major greenhouse warming.

Agriculture in the developing countries would also be affected by changing climate. An average global warming of 4°C is expected to result in a 2.5–4°C increase in regional temperatures between 35° North latitude and 20° South latitude. There is some evidence that increases in tropical and subtropical temperatures would result in overall reductions in some crop yields (115). Food production in many developing countries has increased partly through the expansion of cultivation into the more marginal lands. This process may be increasing the sensitivity of agriculture to climatic change (116).

Climate Change, Sea Level Rise, and Coastal Impacts

Since the turn of the century, the ocean surface temperature appears to have risen by 0.6 ± 0.3°C (117), a warming effect that correlates with the increase in the earth's surface temperature. Measurements of relative sea level at the same time suggest a global average rise of 1–3 millimeters per year (118). If the earth's atmosphere continues to warm, further rises in the global sea level are expected, due partly to the melting of land ice and partly to thermal expansion of the oceans' upper layer.

Large gaps and uncertainties in our understanding of oceans and glaciers make it difficult to predict the effects of further global warming on sea level. For example, knowledge of ocean circulation near and under Antarctic ice shelves is limited, and the models that are currently used for computation of thermal expansion generally do not incorporate the essential physics of deep-water formation and movement (119).

Because the uncertainties involved in estimating the effects of various factors on sea level between now and the year 2100 are large (assuming a doubling or thereabouts in the CO_2 concentration), predictions of the sea level rise vary considerably. One estimate is a rise of 70 centimeters over the next 100 years (120), another that a global rise of 144–217 centimeters by 2100 is most likely (121). Another more recent estimate is that a global warming of 1.5°–4.5°C would lead to a sea level rise of 20–140 centimeters. (See Box 10.1.)

An increase in the global sea level of one or two meters would significantly affect coastal activities. A rise of two meters would inundate some major coastal regions, parts of Louisiana and Florida in the United States (122), for example, and would flood many coastal beach resorts and marshes and low-lying flood plains along rivers and bays. A 0.3-meter rise would erode most sandy beaches along the U.S. Atlantic and Gulf coasts 30 meters inland and could destroy buildings, roads, and other structures and cause the intrusion of salt water into groundwater supplies (123).

It seems unlikely that even intensified research will make it possible to foresee the geographical patterns of a climatic change in significantly greater detail before clear signs of an ongoing change are apparent (124). But there is a consensus among scientists that the greenhouse effect is leading to major climatic changes. This view was reflected in the Villach Conference statement, which called for prompt initiation of policy studies by governments and international agencies in order to better assess the implications of a warmer climate and evaluate ways to anticipate, mitigate, or prevent climate change. (See Box 10.1.)

RECENT DEVELOPMENTS

INTERNATIONAL EFFORTS TO COMBAT ACID DEPOSITION AND TRANSBOUNDARY POLLUTION

The Organization for Economic Co-operation and Development and the U.N. Economic Commission for Europe have done much to bring about international consensus on the need to control emissions of sulfur and nitrogen, but the European Economic Community (EEC) is unique in its ability to impose binding directives on its member states (Belgium, the Netherlands, Luxembourg, West Germany, Denmark, France, the United Kingdom, Italy, Ireland, and Greece) by unanimous action. During the mid-1970s and early 1980s, the EEC imposed increasingly stringent standards on the sulfur content of fuels. The Commission of the European Community has recommended directives for its members that require the best available control technologies to be used in all new stationary sources of SO_2 emissions. The growing international commitment to action on the emission of acid precursors engendered a July 1985 directive implementing auto exhaust emissions standards designed to reduce sulfur and nitrogen oxide emissions by 60 percent. These reductions will be achieved through the phased introduction of catalytic converters on vehicles and increasing the use of unleaded petrol through 1993. (For a more thorough discussion, see Chapter 12, "Multiple Pollutants and Forest Decline.")

VIENNA CONVENTION FOR THE PROTECTION OF THE OZONE LAYER

On March 22, 1985, representatives of 20 nations concluded the first international environmental agreement providing an anticipatory response to an emerging problem (125). The Vienna Convention for the Protection of the Ozone Layer (126) is the first world-wide legal instrument directed to the protection of the atmosphere as a resource (127). The convention represents an important breakthrough for the United Nations Environment Program, which has acted as secretariat for government meetings on the ozone layer for almost a decade.

The exchange of information concerning production of chlorofluorocarbons is considered particularly significant, especially since the U.S. Chemical Manufacturers Association stopped reporting global production data several years ago because of the lack of reporting by the Soviet Union and Eastern Europe (128).

Despite extended efforts to include a protocol on control strategies, the convention does not do so (129). Two blocs of countries, the EEC and the Toronto Group (the United States, Canada, Finland, Norway, and Sweden), were unable to reach a compromise. The EEC proposed a limit on production capacity and a 30 percent reduction in unessential uses of CFCs, while the Toronto Group proposed more immediate and substantial reductions in aerosol uses coupled with a ceiling on per capita usage (130).

A resolution adopted by the parties to the convention provides for continued efforts by UNEP and a working group to conclude a protocol, and it authorizes UNEP to convene a Diplomatic Conference in 1987 for that purpose. The resolution calls on nations to control their CFC emissions "pending the entry into force of a protocol."

Another important result of the convention is the creation of a new permanent institution to oversee its implementation. Secretariat functions will initially be assumed by UNEP until the parties act. The convention will become effective upon ratification by 20 countries. Most countries that produce and use significant amounts of CFCs are expected to ratify, with the possible exception of Japan.

NUCLEAR WINTER

During the first half of this decade, scientists identified for the first time a human influence on climate that appears to be more important than any other—nuclear war. In the 1970s, there were various assessments of the long-term global effects of nuclear war, notably that by the U.S. National Academy of Sciences (131), but none of these studies identified climatic change as a major consequence.

In 1980, scientists theorized that the mass extinction of species that occurred 65 million years ago could be attributed to the blocking out of sunlight by a dust cloud tossed into the atmosphere by the force of an asteroid striking the earth (132). A possible parallel between the dust-lofting effect of an asteroid and that of a sizable exchange of nuclear warheads was quickly recognized, encouraging a fresh look at the consequences of nuclear war (133). In 1982, Paul Crutzen from the Max Planck Institute for Chemistry and John Birks from the University of Colorado, Boulder, were the first to suggest that smoke and soot generated by large urban and forest fires might induce profound changes in weather. Their suggestions stimulated further research and appraisal world-wide (134). The possible effect of dust and sooty smoke on climate in the wake of a nuclear war is known as "nuclear winter" (135).

The nuclear winter hypothesis has been examined and refined considerably since it was first advanced (136). Misgivings and reservations about the findings were voiced, partly because they were so much at variance with conventional thinking, partly because they had profound implications for prevailing nuclear strategic policies, and partly because of the uncertainties and complexity of the underlying atmospheric physics (137). The principal scientific criticism was that the study by Richard Turco and others had used a simple one-dimensional model of the climate that ignored seasonal effects, cloud feedback, and the effects of atmospheric winds. Nevertheless, subsequent studies have confirmed that the potential exists for a major climatic disaster (138,139,140,141).

The latest and most thorough assessment of the climatic and associated biological effects of nuclear war was published in September 1985 by the Scientific Committee on Problems of the Environment (SCOPE) (142). The SCOPE report is based on a two-year study in which more than 300 scientists from 30 countries participated. According to the SCOPE scenario, 6,000 megatons of nuclear explosives (involving more than 12,000 warheads) would be detonated, injecting as much as 50–100 million metric tons of smoke into the atmosphere, 30 million of which would be light-absorbing carbon. The study concluded that the smoke would rise higher than previously thought. Much of the dust and soot would be driven into the stratosphere, where it would stabilize. Trapped above altitudes where precipitation occurs, the smoke would remain for months, and possibly more than a year. If the 30 million metric tons of carbon were to spread over the mid-latitudes of the Northern Hemisphere, the sunlight reaching the ground would be reduced by at least 90 percent. Smoke clouds over some areas would blot out all incoming sunlight.

Critics of the nuclear winter hypothesis have argued that as the atmosphere cooled beneath a smoke cloud, condensation processes would scavenge aerosols (143,144). The SCOPE report concludes, however, that condensation would not affect the upper levels of the aerosol layer and that the amount of water actually condensing would in any case be limited, so that not enough aerosols would be removed to prevent the nuclear winter effect (145).

Perhaps the SCOPE report's major finding is that the majority of the world population would be facing starvation in the aftermath of a nuclear war due to disruptions in agricultural productivity and/or food trade and aid. In Africa, for example, 100–450 million people could run out of food within the first 10 days of a war in which no nuclear weapons struck the continent. The study found that starvation and other indirect effects of a nuclear war could have a bigger impact on both combatant and noncombatant countries than the direct effects of blast, heat, and radiation.

Within the past four years, the nuclear winter concept has rapidly moved from being an interesting and novel idea to one that has been heavily scutinized and widely accepted by the international scientific community. Despite that, it has not yet influenced nuclear strategic thinking.

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12. A downward trend is defined as a change of at least −3 percent; an upward trend is a +3 percent change.
13. *Op. cit.* 2, p. 47.
14. *Op. cit.* 1, *Compendium*, Table 2.2A.
15. In the literature, particulate matter is referred to as total suspended particulates (TSP) or suspended particulate matter (SPM). SPM is used here.
16. There are two chief methods for measuring suspended particulate matter—the smoke shade method and the gravitimetric (high volume) method; they may differ by a factor of 2 or 3. The SPM data collected by these two methods are reported separately. The gravimetric/high volume method is used in North America, parts of Europe, Asia, and Australia; the smoke concentration method in parts of Europe, South America, and New Zealand.
17. There can be a disparity between trends in emissions and in air quality. Emission estimates represent total particulate emissions (both large and small) without any distinction among particle sizes, but the large particles are more likely to settle out of the atmosphere and not be measured by air quality monitoring equipment used to measure suspended particulate matter.
18. *Op. cit.* 10.
19. *Op. cit.* 2.
20. *Op. cit.* 2, Annex 4.
21. *Op. cit.* 2, Annex 4.
22. *Op. cit.* 2, Annex 4.
23. *Op. cit.* 2, Annex 4.
24. *Op. cit.* 1.
25. CO monitoring sites are often located in traffic saturated areas and, therefore, reflect local air quality conditions. If the air quality levels at these locations improve, it is generally at a faster rate than the rate for nationwide reduction in emissions.
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35. *Op. cit.* 30 and 33.
36. *Op. cit.* 30.
37. *Op. cit.* 33.
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11. Policies and Institutions

Are the world's institutions up to the management tasks suggested by the preceding chapters? Is there sufficient expertise, money, and political will to protect fragile ecosystems like the tropical forests, manage highly stressed environments like the semi-arid crop and range lands of Africa, provide essential services for rapidly expanding populations, and regulate pollutants that travel thousands of kilometers across many national boundaries? Are policies and the means to execute them keeping up with the environmental challenges of today's generation and the next? These are big and important questions. This chapter presents some answers, albeit preliminary and partial ones given the scope of the subject and space limitations.

SETTING THE STAGE

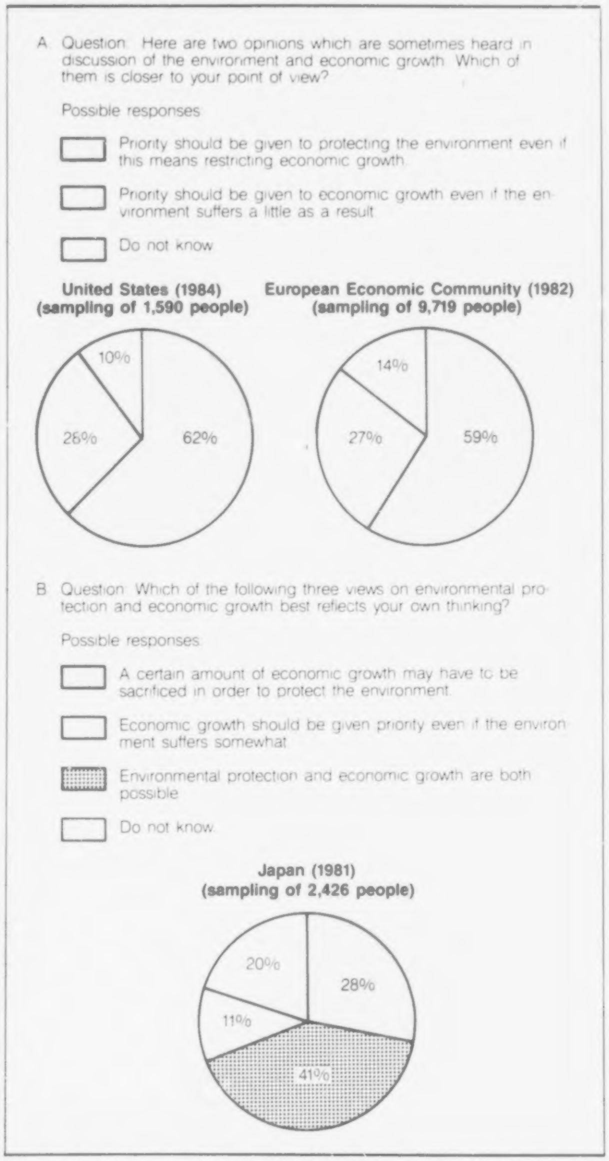
Awareness of human impact on the natural environment has grown rapidly over the past two decades. It has been manifest in countless conferences, meetings, publications, and debates. Many have taken an intelligent guess at what the future holds and have reacted with alarm; many more with numbed complacency. Still others have accused those who point out adverse trends of alarmism or pseudoscience (1). There is no consensus.

Forming a considered evaluation of institutional progress is made even more difficult by the scale and geographical scope of the issues. In 1982, a report entitled "Economic and Ecological Interdependence" (2) by the Organization for Economic Co-operation and Development (OECD) pointed out that the growing interdependence of the international economic and political system had become a central concern. This interdependence is seen to cover not only population, migration, energy, food, financial transfers, and technology, but also the environment and, increasingly, the ecological basis for economic activity. "Understanding of this interdependence and its implications can lead to hope or despair," the report concluded, "depending on one's view of the will and capacity of Governments to make necessary adjustments within and among their countries."

Political will can be strongly affected by public opinion, which is not easy to pin down. Although the state of the environment is not typically an issue that wins or loses elections, opinion polls conducted in the developed countries show that the long-term condition of the planet and, in turn, the quality of life on it are of surprisingly significant public concern (3). (See Figure 11.1.) And to judge from the number of organizations courting such opinion, the politics of the environment are stronger than ever.

Despite all the activity, it is easy to mistake the degree of real progress from inside the environmental community. People intimately involved with a set of issues so loudly debated and discussed necessarily think everyone else is concerned. There is also a new difficulty in choosing priorities. In the world of fundraising for crisis

Figure 11.1 Surveys of Public Opinion about Environmental Issues in Selected OECD Countries



A. Question: Here are two opinions which are sometimes heard in discussion of the environment and economic growth. Which of them is closer to your point of view?

Possible responses:

☐ Priority should be given to protecting the environment even if this means restricting economic growth.

☐ Priority should be given to economic growth even if the environment suffers a little as a result.

☐ Do not know.

B. Question: Which of the following three views on environmental protection and economic growth best reflects your own thinking?

Possible responses:

☐ A certain amount of economic growth may have to be sacrificed in order to protect the environment.

☐ Economic growth should be given priority even if the environment suffers somewhat.

▨ Environmental protection and economic growth are both possible.

☐ Do not know.

United States (1984)
(sampling of 1,590 people)
10%
26%
62%
European Economic Community (1982)
(sampling of 9,719 people)
14%
27%
59%
Japan (1981)
(sampling of 2,426 people)
20%
28%
11%
41%

Source: Organization for Economic Co-operation and Development (OECD), *State of the Environment 1985*, (OECD, Paris, 1985) p. 256.

relief there is talk of "compassion fatigue." Those concerned with environmental issues might recognize "comprehension fatigue" as everything comes to be understood as linked to everything else.

But certainly, the state of the world's natural environment, as an issue, has matured since the days of the U.N. Conference on the Human Environment (the Stockholm Conference) in 1972 (4). Statements of alarm have become practical agendas for improvement. At the rhetorical level, at least, environmental management is being seen less as a roadblock to economic development, and more as a necessary condition for it. Achieving sustainable development—by way of environmentally and socially sensitive economic growth—has become the new agenda.

While the term "sustainable development" has slipped into common parlance, its meaning remains elusive. In an international meeting it is used by those on the left and the right of the political divide. Natural and social scientists refer to it. It is applied to macroeconomic and microeconomic problems alike. It is all things to all people: a comfortable, but ill-defined concept. Various authors have described what is *not* meant: excess pesticide use leading to pesticide resistance; poor agricultural practices leading to soil erosion and dams that silt up; excess pollution leading to environmental hazards and decay; planned obsolescence leading to a waste of resources and so on (5). Others have pointed to management decisions that fail to consider social equity, cultural sensitivity, the involvement of people, ecological concepts such as biological stability and resilience, and environmental ideas on minimizing waste by recycling and renewal.

Attempts to arrive at a positive definition usually produce a result too general to be useful. For instance, the *World Conservation Strategy* says that development is: "...the modification of the biosphere and the application of human, financial, living, and non-living resources to satisfy human needs and improve the quality of human life. For development to be sustainable it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long-term as well as the short-term advantages and disadvantages of alternative actions" (6). More specific definitions usually reflect the preoccupations of their authors. For example, a panel of business leaders proposed a four-part description of sustainable development that is useful though its source is readily identifiable: non-renewable resources are used in a technically efficient manner; earnings from non-renewable resource exploitation are used to build the productive capacity of a country through investment in physical and human capital; the productivity of renewable resources—soils, forest, fisheries—is protected and maintained for future use; and valuable but non-marketed services provided by environmental resources—such as clean air, potable water, recreation opportunities—are also protected and maintained (7).

What then are some essential features of this important but slippery concept? First is the effort to unite the ingredients for current economic output with the future productivity of the resource base (8). Second, the creation of wealth is measured over the long (rather than the short) term, though neither period is defined. A third common element is more sophisticated assessment of costs and benefits that account for the indirect costs of economic activity (such as the impacts of pollution distant in space or time), the value of non-marketed goods and services (such as regulation of the hydrologic cycle by forests, or the aesthetic value of undisturbed wilderness), and impacts on commonly-owned property and on the global commons (such as the stratospheric ozone layer). A fourth feature of most definitions is that "development" is used to mean economic growth (rather than something that happens to developing countries), making the concept applicable to all countries.

This chapter is concerned with how sustainable development, though still a loose ideal, is manifesting itself in institutional terms. It reviews selected political initiatives, changes occurring in environmental evaluation and assessment, the availability of environmental data, some of the key changes in law and administrative practice, recent changes in development assistance, and unanswered questions being raised by the non-governmental community.

THE PROCESS OF CHANGE: SIX INITIATIVES

The emerging recognition that environmental protection and economic growth can be complementary goals is the result of many pressures working on governments. Most are domestic in orientation but some are organized internationally. Change at the international level takes time. What may be accepted in the corridors of New York, Geneva, or Nairobi is only rhetoric until carried back for national debate and agreement. As a result similar statements are repeated again and again before they are translated into concrete action.

Six recent initiatives, each a variation on a theme, have set out the prevailing view that is creeping into action. Each is having an impact on policy formulation by influencing different constituencies which in turn pick up the concepts. All are parts of the process of change.

The Inter-Parliamentary Union Meeting, 1984

The Inter-Parliamentary Union (IPU) conference on the environment brought 98 legislators from 44 national parliaments together in Nairobi to encourage them to create greater environmental awareness within their own governments. In four days, conference delegates produced 93 recommendations, covering nearly every device for national and international action (9).

Common problems such as desertification and transboundary air pollution understandably united many of the delegates. But even normally divisive issues produced some strong recommendations. The IPU distributed its recommendations to all participating parliamentary groups, and the United Nations Environment Program's (UNEP) Executive Director, Mostafa K. Tolba, promised a follow-up meeting for 25 national delegations in 1986. Addressing the conference, Martin Holdgate, Chief Scientist of Great Britain's Department of the Environment, put forward five propositions that mark the present consensus on international efforts to safeguard the environment (10):

- First, that the physical, biological, social and economic linkages of the world are so all-embracing that an international dimension must be looked for in most environmental problems, and that decisions on the policies to solve them will increasingly be taken internationally.
- Second, that the experience of the past ten years shows that environmental problems can be, and are being solved. These problems do *not* justify the pessimism about the future that dominates much of the press coverage in Europe and North America.
- Third, that an approach can be made to work only if there is genuine cooperation between rich and poor nations.
- Fourth, that we shall adequately manage the planet only if we think and work on nature's time scales, and apply measures that are in harmony with the pulse of the earth.
- Fifth, that we can deal with major environmental problems only if we act in depth. International discussions alone achieve little or nothing. There has to be a sound supportive basis of national policy, national law, national executive structure, national commitment, national education, training, communication, and national science.

"The Global Possible" Conference, 1984

In May 1984 the World Resources Institute (WRI) convened a meeting of 75 government, science, industry, environment, and development leaders from 20 countries to identify problems of global significance and to propose strategies for their solution (11).

The conference's summary statement was cautiously optimistic: "At a time when bleak predictions are all too familiar, the Global Possible Conference was convened to re-examine the relationship between Earth's resources and the human future. The Conference accepted that these predictions could be accurate. But its central and emphatic message is that they need not be—that it is possible to build a world that is more secure, more prosperous, and more sustainable both economically and environmentally (12)."

The conference identified five transitions "essential to a world at once sustainable and renewed":

- "A demographic transition to a stable world population;
- "An energy transition to an era in which energy is produced and used at high efficiency without aggravating other global problems;
- "A resource transition to a reliance on nature's 'income'; and not depletion of its 'capital';
- "An economic transition to sustainable growth and a broader sharing of its benefits; and
- "A political transition to a global bargain grounded in complementary objectives between North and South (13)."

In all, 84 specific policy recommendations emerged in 13 interrelated categories covering population, poverty, and development, as well as the more familiar themes such as urban environment, tropical forests, biological diversity, atmosphere and climate, international assistance and the environment, and assessment of conditions and trends. This conference, to judge by the number of citations of its findings internationally, again caught the emerging consensus.

The World Commission on Environment and Development, 1983

The World Commission, established by the United Nations in December 1983, is organized outside the U.N.

system, but will present its report, *Common Future*, to the General Assembly in 1987. Significantly, 14 of the Commission's 22 members are from developing countries. According to Gro Harlem Brundtland, its chairman, the group intends to:

- Re-examine the critical issues of environment and development, and formulate innovative, concrete, and realistic action proposals to deal with them;
- Assess and propose new forms of international cooperation on environment and development that can break out of existing patterns and influence policies and events in the direction of needed change; and
- Raise the level of understanding and commitment to action on the part of individuals, voluntary organizations, businesses, institutions, and governments (14).

Not all governments welcome the Commission. Some fear the pressures that may be generated for new initiatives; others are skeptical about putting the world to rights through the thoughts of a worthy few. Nevertheless, the Commission's *raison d'être* was due, at least in part, to the U.N. system's failure to change the worst of environmental deterioration since the Stockholm conference. Most important, it is a route by which governments can shift ground toward a more interdependent world view should they wish.

From the outset the Commission's agenda has differed from the standard agenda of environmental and natural resource issues. It places the interdependence of states at center stage, in terms of transboundary pollution, transboundary management needs, common property resources (e.g., genetic diversity, the oceans, and the atmosphere) and, not least, economic activity. The "new" agenda joins issues across the traditional sectoral lines. It identifies "energy, environment and development"; "food security, agriculture, forestry and environment"; and "international economic relations, environment and development" as integrated subjects (15). Though not truly novel, the Commission's "new" agenda represents an unusual attempt at the intergovernmental level to link environmental disruption to its major causes: *bad* development or *no* development at all. In effect, the Commission's agenda restates the view that those who promote an environmental ethic are not "antigrowth," but instead are solidly based in the business of economic development.

The World Conservation Strategy, 1980

Many traditional wildlife conservationists made their first contact with the broader environmental agenda in 1980 with the drafting of the World Conservation Strategy (WCS). Its impact continues to be felt, helping bring about the new approach toward sustainable development. The United Nations Environment Program commissioned the International Union for Conservation of Nature and Natural Resources (IUCN) to prepare the Strategy and joined with the World Wildlife Fund in supporting its preparation.

The WCS was first and foremost an attempt to bring conservation and development together: "Human activities are progressively reducing the planet's life-supporting capacity at a time when rising human numbers and consumption are making increasingly heavy demands on it. The combined destructive impacts of a poor majority struggling to stay alive and an affluent minority consuming most of the world's resources are undermining the very means by which all people can survive and flourish" (16). To some people, the emphasis upon man's, as opposed to nature's, needs was out of balance. But that is not the point. The conservation lobby, once so strongly associated with wildlife protection, had come of age. In effect, it was saying: "we want a better style of development—sustainable development—because that is the only way to achieve conservation."

The task of drafting was in itself a remarkable feat of consultation and review across a vast range of international opinion and expertise. The result, in summary, is simple and straightforward:

1. It explains the contribution of living resource conservation to human survival and to sustainable development,
2. It identifies priority conservation issues and the main requirements for dealing with them, and
3. It proposes effective ways of achieving the strategy's goals.

The attempts by IUCN to have national conservation strategies prepared the world over is a continuing program (17). In many cases it is stimulating the integrative approach to the environment in previously barren administrations. By November 1985 about 40 countries were preparing or had prepared national or sub-national conservation strategies (18). (See Part IV, "Policies and Institutions," Table 12.2.) A critical review of progress made and changes needed will take place in 1986 at an international conference in Ottawa.

The World Industry Conference on Environmental Management, 1984

Business leaders tend to be realists when it comes to assessing the potential for economic growth. A small but growing number realizes that, especially in the Third World, the cycle of poverty and natural resource degradation can be broken only by creative management of both economic growth and resource conservation.

Industry, en masse, blessed the current consensus at the first World Industry Conference on Environmental Management (WICEM), convened at Versailles by UNEP and the International Chamber of Commerce (ICC) in late 1984. Some 300 participants were expected, but more than 500 attended, representing 71 countries.

The meeting produced 15 broad recommendations grounded in five principles on the environment and development that repeat the often-heard ideals. Sustainable economic development was mentioned along with environmental management, planning cycles, cost benefit analysis, anticipatory policies, and other measures (19). WICEM's 15 recommendations, if taken seriously by industry, could dramatically improve how commerce and the environment can be reconciled.

Unlike many other conventions, WICEM did not lead to a new institution to implement its agreements. Rather, the co-sponsors, UNEP and ICC, agreed to strengthen or modify their own structures to accommodate the fruits of this collaboration.

Shortly after attending WICEM, Maurice Strong, Secretary General of the 1972 Stockholm Conference and a businessman and policymaker on international environment and development issues, urged environmental activists "to establish closer links and better understanding with business and industry as well as with governments and inter-governmental organizations." Business and industry are "the principal agents through which environmental correction and prevention must take place," he said. "And they are increasingly sensitive and responsive to these needs. Industry has become far more environmentally oriented than many in the environmental community have yet been prepared to recognize" (20). In the developed countries environmentalists are beginning to drop their confrontational attitudes toward industry in favor of a cooperative approach. In the United States, for example, groups comprised of representatives of industry and environmental organizations have undertaken to formulate joint policy on a range of issues from pesticide policy to hazardous waste disposal. And while relatively few business leaders fully share Strong's views, many corporations, large and small, have made important positive strides.

The Global Meeting on Environment and Development for NGOs, 1985

In February 1985, the Environment Liaison Center (ELC), with support from UNEP, convened the Global Meeting on Environment and Development for Non-Governmental Organizations (NGOs) at its Nairobi headquarters.

Reflecting the growing confidence of the worldwide NGO community, the meeting brought together for the first time the leaders of more than 100 citizens groups, voluntary organizations, and other private groups from 48 countries to discuss common issues in environment and development. A broad spectrum of environmental, development, relief, population, and religious organizations was represented (21).

Anil Agarwal, chairman of the ELC, struck the theme: "what we face today is nothing less than the failure of the development process, the development paradigm, that we have been so avidly running after. . . Finding and implementing a new development process, an equitable and sustainable development process, is the biggest intellectual and political challenge we face"(22).

The conference participants answered this challenge not with a final declaration (which they feared might smother the diversity of cultures, values, and models of sustainable development represented there), but with a commitment to actively pursue 119 proposals stressing citizen participation and the role of NGOs. Needed actions were identified in more than a dozen different fields, including the traditional sectors (e.g., agriculture, forests, water, and energy) and several cross-cutting areas (e.g., development assistance, appropriate technology, international debt, and impact of militarization).

The meeting also highlighted the need for a two-pronged approach involving both "macro" and "micro" levels. Macro issues concern broad policy questions and lend themselves to lobbying governments and international agencies through the media, membership efforts, and leadership education. These approaches are quite distinct from strengthening grass roots capabilities to, for example, manage community forestry projects at the micro level. Both approaches were combined in a "No More Bhopals" network launched at the meeting.

This gathering may have sparked a new phase of NGO cooperation that could improve NGO effectiveness both in national capitals and in their communities.

Three Essential Capacities

Many of the hundreds of recommendations offered by these six recent initiatives require three essential capacities, principally at the national level:

1. That countries actually know the status and trends of their natural resources and environment—assessments are available.
2. That they can make and execute environmental policy—they have the capacity to manage.
3. That their environmental and resource management programs operate in a supportive larger context—international cooperation, external financial assistance, public support and participation, and a helpful attitude in the business community all contribute.

Most developing countries are weak on all three counts. The developed countries tend to be much more diverse. Some still know very little about the actual state of their resources, for example, though they may possess strong management capacities.

The next sections deal separately with the tools available for progress on each broad front. As with the political initiatives just discussed, we do not attempt to cover everything. In a description of the most recent highlights, much of importance has had to be omitted.

ASSESSMENT

Accurate data on demographic and resource conditions and trends are the first prerequisite to sound policy. In the environmental field, as this volume demonstrates over and over again, the availability of adequate data can by no means be taken for granted. The next necessity is the ability to assess both the baseline information and the pluses and minuses of alternative projects and policies. In this respect, also, many countries' capacities are terribly weak.

Collecting Data

In the 1970s, data collection focused on pollution. But even in this field, progress has been slow. Basic information on the extent and consequences of air and water pollution is still lacking for much of the world. Moreover, the meaning of the mass of data that is available is limited by large gaps in knowledge that have come to light from many fields of research.

Also in the 1970s, the first large-scale regional programs were undertaken to measure pollutants of common concern. For example, around the Mediterranean Sea more than 80 institutions are today engaged in a cooperative program of research and monitoring that has survived the political vicissitudes of the area. The resulting assessments have led to regional conventions and national activities to reduce pollutant flows into the shared sea. This regional program has been replicated in a dozen similar "Regional Seas" programs serving some 120 coastal states (23).

New pollution problems continue to emerge—such as the recent indications of widespread contamination of groundwater—for which severe analytical problems remain to be overcome. But, by and large, the procedures for measuring and monitoring pollutants and for taking them into account in national planning and decision making are now reasonably well understood. They can be applied where there is the will.

On the other hand, accurate measurement and monitoring of many forms of resource degradation (e.g., deforestation, desertification, soil erosion, salinization, and waterlogging) are variously spotty, unreliable, or still impossible. The tools to accurately locate and measure natural resources are confined mostly to *non*-renewable resources, such as minerals, and oil and gas, for which there is a strong commercial motivation.

As recently as 1982, UNEP's authoritative "The World Environment—1972–1982" concluded that: "There are general local and/or regional figures for the extent of deserts, rangelands, farmlands, and other major land-use categories, but detailed information about their conditions—and rates of degradation—are rarely available" (24).

The opportunity for improved assessment of these natural resources rests heavily on the development of airborne and satellite sensors that measure signal strength from the earth's surface in various spectral frequencies and convey these data in digital form. Unlike the chemical emulsion plates on which high-altitude "pictures" used to be based, such data are now transmitted and recorded on magnetic tape as signals that can be converted into images, much like those on television screens, though far more detailed.

The availability of such data has forced the development of machines and software that can align remote sensing data with the ground elements to which the data correspond. Called Geographical Information Systems (GIS), this technology can present an image that geographically corresponds to a given area, and can realign other data points to the same area, even if acquired at different times, from different sensors. Although these techniques have obvious application for military and intelligence uses, the requirement of the U.S. National Aeronautics and Space Act of 1958 that "activities in space should be devoted to peaceful purposes for the benefit of all mankind" has meant that the results of the U.S. National Aeronautics and Space Administration's (NASA) extensive data collection, and the techniques it has developed for interpretation of the data, have been placed in the public domain.

In 1985 the first formal transfer of this capability to an international organization took place when The Global Resource Information Database (GRID) was dedicated in Geneva by UNEP and the Swiss government. GRID consists of the machines and the software developed by NASA and made available to UNEP and the U.N. system to analyze data collected by these international organizations (25).

GRID's immediate application will be to integrate and improve the analysis of various data sets already built up by UNEP's Global Environmental Monitoring System (GEMS) program, with data sets from the World Health Organization, the Food and Agriculture Organization, the World Meteorological Organization, and others. If the program works as intended, dramatically improved assessments of the planet's environmental trends can be carried out and kept up to date (26).

The GRID facility will also be a training site, helping to transfer digital analysis skills to the national level, where they are generally absent. Although the hardware and software at GRID in Geneva represent an investment of many millions of dollars, the growing capacities and declining costs of microcomputers put the capability to carry out such analysis within reach of any university, and make it an attractive area for donor agencies to support.

Already, work underway at the World Bank uses data generated by GRID to analyze soil, vegetation cover, and meteorological conditions in some African countries as a prelude to finding new ways to increase local food production on a sustainable basis. This process can be greatly accelerated in future years as countries develop their own means to carry out such analyses in more detail. Ultimately, perhaps, such data and the skills to interpret them may become routinely available even at the local level.

National and Sectoral Assessments

The first complaint of policymakers and politicians, when confronting a new problem, is that they do not have enough information for making decisions, and, more often than not, they are correct. Until recently, few countries took stock of their environmental conditions and trends except as they related to specific activities such as mining, forestry, irrigation, or energy production. But with the growing sensitivity of governments to environmental issues and the increasing number of international agreements dealing with resources, the need for both national and international data on the environment has been dramatized repeatedly.

Before the Stockholm Conference, only Japan and the United States compiled comprehensive national reports on their environmental conditions; both began doing so in 1970, although many others had sectoral reviews. Since then, national state-of-the-environment reports have been published by: France in 1978; Belgium in 1979; Yugoslavia in 1980; India in 1982; the Philippines and Sweden in 1983; Malaysia in 1984; and Finland, Chile, Ireland, and Poland in 1985. Country state-of-the-environment reports are being drafted in Burkina Faso, Sudan, Saudi Arabia, and Canada. (See Part IV, "Policies and Institutions," Table 12.2.)

Many other countries, such as the United Kingdom, rely on standing committees or commissions to periodically review key aspects of national environmental policy.

State-of-the-environment reports, environmental profiles, and national conservation strategies are all variations on the national assessment theme. They are prepared by governments, agencies, or non-governmental organizations.

The two editions of *The State of India's Environment* (1982 and 1985) provide an excellent example of the latter. Prepared by the Centre for Science and the Environment in New Delhi (27), the reports attempt to cover the gamut of India's vast and complex environment, drawing on official and non-governmental data alike. The advantages of an independent assessment are that it can evaluate both business and government policies, and can point out information gaps—things governments are often reluctant to do. In this case, the reports have dealt with such touchy subjects as the loss of common property resources for the poor, and corruption or abuse of the country's natural resource stock by various agencies, domestic and foreign.

General assessments of a country's environmental condition are, without question, a key step toward building public awareness and fostering sound decision making. But such overall assessments are generally not directly useful for management purposes. They often fail to bring enough focus or detail together on particular sectors to satisfy the specialist, the relationship between sectors is often unclear, and the prescriptive elements of the reports are weak. Furthermore, the data are often fragmented and inconsistent.

Related to the preparation of national overviews is the growing tendency of international assistance agencies to call for general environmental appraisals and specific sector reviews where environmental policies are seen to be significant (e.g., in forestry, land use, and renewable energy). The World Bank, the U.S. Agency for International Development (U.S. AID), the European Economic Community (EEC), and other multilateral and bilateral agencies are commissioning environmental reviews of one sort or another. There is great variation in the type, focus, and level of detail of these efforts, and a clear need for some coordination of all this activity through an open international referral system.

An innovative and valuable effort to assess the state of the environment at the international level is now published annually in the United States. *State of the World*, prepared by the Worldwatch Institute, attempts to measure progress in "the extent to which our economic and social systems are successfully adjusting to changes in the underlying natural resource base." It examines issues as diverse as "reducing dependence on oil," "maintaining world fisheries," and "managing rangelands" (28).

Project Assessments

There is also an expanding library of project-specific environmental assessments, which has ballooned since the U.S. National Environmental Policy Act initiated the technique of formal environmental impact assessment (EIA) in 1970. The variations on the theme are legion, as each country or sector has devised a model best suited to its own purposes. A parallel library of reviews and analyses of the process itself has also grown up.

The most comprehensive review of the EIA process as a tool for development in the Third World was prepared for the International Union for Conservation of Nature and Natural Resources (29). Called *Status and Application of Environmental Impact Assessment*, this valuable document sets out the basic methods, experience, and benefits of the EIA process to date and presents a series of recommendations for its use in situations where the administration and basic data are weak. The study shows that EIA procedures are now used extensively by external funding sources as well as by some Third World countries themselves. This review will be updated in 1986 when the results of a joint exercise on the appropriate use of EIAs in development projects by the environmental and development assistance committees of OECD are published.

Underlying the process of environmental impact assessment is an attempt to bypass intuition and to construct a more formal approach to decision making. That is, of course, the purpose of much of planning law, which has a tradition going back decades. An EIA, if well done, has two particular strengths: it forces an integration of natural science with economic evaluation, and it lays out the options considered and—often more important—those *not* considered by the policymaker. On the other hand, nearly all project-specific assessments are carried out late in the planning process and are therefore often seen as a hindrance rather than a useful contribution to good decision making.

For good or ill, much EIA activity in developing countries takes place as a result of, or with the assistance of, external agencies. For instance, few countries in Africa have a formal mechanism for injecting environmental factors into project planning. But this is not universally true. Most members of the Association of Southeast Asian Nations (ASEAN) do have formal EIA policies (30) and have accumulated considerable experience with them.

Improving Assessments

In addition to environmental impact assessment, other methodologies are now being used to bridge the gap between environmental management and development practice, including rapid rural appraisals (31), land capability analysis (32), and more. Perhaps the most important area of progress is in the development of more sophisticated alternatives to traditional cost-benefit analysis; that is, developing methodologies that can express economic, environmental, and ecological change in a common unit of measurement, and within a single planning process or procedure.

In some cases, these new approaches involve modifying the practice of traditional economic assessment. One successful method, called "natural systems assessment with economic valuation," has been formalized and tested enough to have been adopted by the Asian Development Bank (33). Its authors consider that the system has five special features:

1. "Consideration of sustainable use and environmental quality at the earliest stages of project inception;

Box 11.1 Lessons of the Global Models

Predicting the future from current conditions and trends is inevitably risky. For example, the very act of defining a trend often causes policy changes, and these cannot be anticipated. However, in the 1970s, the emerging capacity of computers to handle masses of data led to the flowering of an international school of global modelers. Prominent among the global models were:

- The Forest/Meadows model: Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States.
- The Mesarovic/Pestel models: Systems Research Center, Case Western Reserve University, Cleveland, Ohio, United States; and Technical University, Hannover, West Germany.
- The Bariloche model: Fundacion Bariloche, San Carlos de Bariloche, Rio Negro, Argentina.
- The MOIRA (Mode of International Relations in Agriculture) model: Economic and Social Institute, Free University, Amsterdam, Netherlands; and Agricultural University, Wageningen, Netherlands.
- The SARU model: Systems Analysis Research Unit, Department of the Environment, London, United Kingdom.
- The FUGI model: Engineering Research Institute, Faculty of Engineering, Tokyo University, Tokyo, Japan.
- The United Nations World model: Economic Research Center, New York University, New York, United States; and Brandeis University, Waltham, Massachusetts, United States (1).

An analysis of these models concluded that despite strong differences in approach and methodology, 12 common "messages" could be drawn about the state of the world and its possible futures.

1. "There is no known physical or technical reason why basic needs cannot be supplied for all the world's people into the foreseeable future. These needs are not being met now because of social and political structures, values, norms, and world views, not because of absolute physical scarcities.
2. "Population and physical (material) capital cannot grow forever on a finite planet.
3. "There is no reliable, complete information about the degree to which the earth's physical environment can absorb and meet the needs of further growth in population and capital. There is a great deal of particular information, which optimists read optimistically and pessimists read pessimistically.
4. "Continuing business-as-usual policies through the next few decades will not lead to a desirable future—or even to meeting basic human needs; it will result in an increasing gap between the rich and the poor, problems with resource availability and environmental destruction, and worsening economic conditions for most people.
5. "Because of these difficulties, continuing current trends is not a likely future course. Over the next three decades the world socio-economic system will be in a period of transition to some state that will be, not only quantitatively but also qualitatively, different from the present.
6. "The exact nature of this future state, and whether it will be better or worse than the present, is not predetermined, but is a function of decisions and changes being made now.
7. "Owing to the momentum inherent in the world's physical and social processes, policy changes made soon are likely to have more impact with less effort than the same set of changes made later. By the time a problem is obvious to everyone, it is often too far advanced to be solved.
8. "Although technical changes are expected and needed, no set of purely technical changes tested in any of the models was sufficient in itself to bring about a desirable future. Restructuring social, economic, and political systems was much more effective.
9. "The interdependence among people and nations over time and space are greater than commonly imagined. Actions taken at one time and on one part of the globe have far-reaching consequences that are impossible to predict intuitively, and probably also impossible to predict (totally, precisely, maybe at all) with computer models.
10. "Because of these interdependencies, single, simple measures intended to reach narrowly defined goals are likely to be counterproductive. Decisions should be made within the broadest possible context, across space, time, and areas of knowledge.
11. "Cooperative approaches to achieving individual or national goals often turn out to be more beneficial in the long run to all parties than competitive approaches.
12. "Many plans, programs, and agreements, particularly complex international ones, are based upon assumptions about the world that are either mutually inconsistent or inconsistent with physical reality. Much time and effort is spent designing and debating policies that are, in fact, simply impossible" (2).

References and Notes

1. D. Meadows, *et al.*, *Groping in the Dark—The First Decade of Global Modelling* (John Wiley and Sons, Chichester, 1982), p. 20.
2. *Ibid.*, p. xviii.

2. "Integration of the assessment into both the economic appraisal and the economic planning organization rather than its treatment as a separate, externally generated document added at a later stage;
3. "Quantification and monetization to the fullest extent possible;
4. "Continuous monitoring of indicator parameters for feedback into adaptive management; and
5. "Post-project review to judge the accuracy of predictions and the extent to which mitigative measures were implemented" (34).

While a definite improvement on common practice, this system remains weak in dealing with the monetization of many important parameters (such as esthetic values, human mortality, the services of undisturbed ecosystems, etc.) and in the quantification of costs and benefits that occur in the mid- to long-term (i.e., it proposes no alternative to traditional discounting). But, as in many other instances illustrated in this volume, the system's greatest weakness is that much of what the careful decisionmaker *needs* to know, is unknown. (See Table 11.1 for one example.)

In a different approach, UNEP is working on changing the calculation of national accounts: a key form of economic assessment. The motivation for the change is the imbalance codified in the present international system of drawing up these accounts, namely that man-made assets are valued as productive capital while natural resources are not. Thus, while man-made assets are depreciated, natural resources are not. "As a result," says one economist, "a country could exhaust its mineral resources, cut down its forests, erode its soils, and hunt its wildlife and fisheries to extinction, but measured income would rise steadily as these assets disappeared" (35).

To correct this asymmetry, economists are attempting to devise methods to broaden national income accounts. In this way they hope to adequately account for the depletion of natural resource stocks, the effects of pollution, and other environmental variables in a country's assessment of its economic development. The United

Nations Enviroment Program and the World Bank have sponsored international workshops in 1983, 1984, and 1985. From these exercises it is apparent that "in most countries it would be more appropriate to emphasize separate environmental accounts for subsequent linkage with GNP accounting, that considerable data already exists,. . . and that the most important resources and environmental services to be accounted for and the appropriate levels of aggregation would vary from country to country in accordance with environmental, technological, and social factors" (36). Norway provides an advanced example of natural resource accounting in practice with its long-term program 1986–89 (37).

MANAGEMENT: THE CAPACITY FOR ACTION

A government's ability to move from understanding the condition of its resources to the creation of policy, and from there to the execution of that policy, depends principally on its stability and political legitimacy, and on the availability of funds and adequate human and technical resources. Such general characteristics apply, of course, to all policy and can really be appraised only on a country by country basis.

Narrowing the focus to resource and environmental policy makes the task of evaluating management capacity only a trifle easier. It does, however, highlight a steadily expanding network of instruments and institutions that has grown up over the past three decades. The number, scope, and complexity of these agencies, laws, treaties, guidelines, and the like have increased dramatically during the past 15 years. Yet, they by no means tell the whole story: The best laws in the world mean little in a country unable to apply them; an environmental agency that looks fine on paper will make little difference if its representative is not at the table when decisions are made; and an international agreement honored principally in the breach will change reality very little. Nonetheless these tools provide a sound index of overall trends—certainly management *without* them is impossible in modern societies—and can be used to review in broad outline the capacity for resource management around the world.

National Environmental Agencies

The number of national environmental management agencies skyrocketed in the decade after the 1972 U.N. Conference on the Human Environment in Stockholm. At the time of this conference, 2[illegible] countries, 11 of them in the developing world, had environmental management agencies. Today, more than 140 countries, including 110 developing countries, have them (38), and a listing of the principal agencies runs to several hundred pages (39).

The creation of an agency is one thing; its effectiveness quite another. In developed and developing countries alike, environmental agencies have been plagued by the lack of human, technical, and financial resources and have been very much junior members within the circle of government ministries. Often, heads of these agencies operate at the mid-level, without access to decision-makers at the top. Beyond that, monitoring and enforcement vary widely from close control to none at all.

As government debts have grown, especially in the past few years, environmental agencies and priorities have lost money and influence—sometimes disproportionately (40). OECD closely reviews management trends in its member states, and in 1987 its Vienna Center plans to publish a comprehensive comparison of 14 Eastern and Western European countries. No doubt this report will confirm OECD's earlier assessment that even among these wealthy nations "several countries were unable to devote the resources to environmental programs that were required" (41).

Legislation and Policy

The 1970s were also marked by a rush of environmental and resource-related legislation, especially in the industrial countries. (See Table 11.2.) Within the past few years, the stream of legislation has slowed in the industrial countries, and the emphasis has shifted to implementing the laws already on the books, making changes for greater efficiency or consistency with other programs, and carrying out the necessary research and monitoring (42).

Generalizations about the state of environmental legislation and policy in the developing countries are bound to be crude, since conditions vary widely and few surveys exist (43). In many parts of the developing world, the 1970s were at first a period of antipathy toward, and then gradual acceptance of, the notion that environmental issues are a valid concern. In 1985, Julius Nyerere of Tanzania spoke for many countries inside and outside of Africa when he said, "Until the last few years, Africa regarded environmental concern as an American and

Table 11.1 Discounted Present Value of Costs of Geothermal Wastewater Disposal Under Alternative Schemes in the Philippines

(millions of pesos)

Alternative Options	Direct Costs	Estimated Environmental Costs	Total Measured Costs	Nonquantified or Nonquantifiable Costs
1. Reinjection	138.3	Unknown	138.3	Energy loss
2. Untreated discharge into Mahiao River	120.2	Rice: 7.3 Fisheries: 56.5	184.0	Freshwater fishery, stock health, laundry, bathing uses, human health, sea ecosystems
3. Treated discharge into Mahiao River	359.3	No Estimate Made	359.3	Rice production, lower loss on items in option 2 with the exception of sea ecosystems
4. Untreated discharge into Bao River	81.1	Fisheries: 56.5	137.6	Freshwater fishery, stock health, domestic use, human health, sea ecosystems
5. Treated discharge into Bao River	359.1	No Estimate Made	359.1	Less than option 4
6. Piping into ocean at Lao Point	243.1	Unknown	243.1	Nonquantifiable but high
7. Piping into ocean at Biasong Point	353.2	Unknown	353.2	Nonquantifiable but high

Source: R.A. Carpenter and J.A. Dixon, 1985, Reference 33, p. 29

Table 11.2 Major National Environmental Laws in OECD Countries, 1956–84[a]

	Type of Law					
	General	Water	Wastes	Air	Impact Statement	Other
Canada		1970			1973	1975[b]
United States	1970	1972	1965	1963	1969	1976[b]
		1977	1970	1970		
			1976	1977		
			1984			
Japan	1967	1958	1970	1962		1973[b]
	1970	1970		1968		1973[c]
Australia	1974				1974	
New Zealand		1967		1972	1972	
		1974			1977	
Austria		1959				1973
Belgium		1971	1974	1964		
Denmark	1973	1978	1978			1978[d]
		1980				1979[b]
		1982				
Finland		1961	1978	1982		1923[d]
		1979				1965[e]
France	1976	1964	1975	1974	1976	1977[b]
Germany, Federal Republic of		1957	1972	1974	1975	1976[d]
		1976				
Greece	1976	1977		1983		1977[f]
	1980	1978				1985[g]
Iceland						
Ireland	1976	1977		1977	1976	
Italy		1976		1966		
Luxembourg	1982	1961	1980	1976		1976[j]
Netherlands	1952	1969	1976	1970		1963[h]
	1979	1975	1977			1979
						1983[i]
Norway	1981					1977[b]
Portugal	1976	1977		1980		1976[d]
						1983[b]
	1983					1983[k]
Spain			1975	1972		
Sweden	1969	1969	1975	1969	1969[l]	1964[d]
	1981	1981		1981	1981	1973[b]
		1983				
Switzerland	1983	1971				1966[d]
						1969[b]
						1979[d]
Turkey	1963	1960				1983[d]
		1971				
United Kingdom	1974	1961	1974	1956		1974[j]
		1974		1968		1975[c]
				1974		1981[d]

Notes:
a. Some federal countries such as Australia and Austria have laws at the state level.
b. Law on the general control of chemicals.
c. Law on compensation.
d. Law on nature conservancy.
e. Law on public health.
f. Law on protection of forests and forest areas.
g. Law on noise and air pollution from motor vehicles.
h. Law on nuclear energy.
i. Law on soil.
j. Law on noise.
k. Law on territory planning.
l. Essentially a specific administrative procedure.
Source: Organization for Economic Co-operation and Development, Reference 41, p. 242.

European matter. Indeed there was a tendency to believe that talk of the environment was part of a conspiracy to prevent modern development on our continent! Now we have reached the stage of recognizing that environmental concern and development have to be linked together if the latter is to be real and permanent. The question is how to do this" (44).

As acceptance of the validity of environmental concerns slowly spread, a recognizable theme of the many statutes passed during the decade was the centralization of authority at the national level. But of course, there are exceptions, even within individual countries. In India, for example, the 1981 air pollution control act covers all states, but the water pollution law is applicable only to those states that adopt it.

As to content, most developing countries are by and large still in the "react and cure" phase, while the developed nations are beginning to address a new agenda of "anticipate and prevent," though the earlier agenda is far from complete. In numerous developing countries, effective "react and cure" remains a distant goal, even where the desire to correct a problem is present. Air pollution in urban areas, for example, is chronic. Emissions legislation is typically inadequate, and those laws that do exist are poorly enforced. Many factories do not have pollution control equipment, even if such equipment has been mandated. Because of a lack of zoning policies, pollution-intensive industry has frequently been situated near or within residential areas, reinforcing the impact of industrial air pollution. Moreover, power plants and factories often burn high-sulfur coal and heavy residual oil, releasing large quantities of sulfur oxides and particulates into the urban atmosphere (45).

As for the developed countries, the issues cited in the Final Communiqué of the 1985 Bonn Economic Summit (attended by the United States, United Kingdom, France, the Federal Republic of Germany, Japan, Canada, and Italy) provide as good a snapshot as any of the concerns now occupying center stage:

> New approaches to strengthening international co-operation are essential to anticipate and prevent damage to the environment, which knows no national frontiers. We shall co-operate in order to solve pressing environmental problems such as acid deposition and air pollution from motor vehicles and all other significant sources. We shall also address other concerns such as climatic change, the protection of the ozone layer and the management of toxic chemicals and hazardous wastes. The protection of soils, fresh water and the sea, in particular of regional seas, must be strengthened (46).

The themes here are evident: a respectful bow toward "anticipate and prevent" policies; a concern with transboundary problems, especially those of acid deposition and associated forms of air pollution (see Chapter 12, "Multiple Pollutants and Forest Decline"); and an emerging recognition of fully global issues such as climate change. Finally, there is mention, as there might not have been a decade earlier, of the need for basic resource conservation; in this case, of soils. And the unmet cleanup needs of the "react and cure" agenda are still a high priority.

The newly prominent problems of transboundary pollution control are forcing sacrifices and adjustments that previous international agreements generally did not. In the past, international environmental controls have advanced at a rate largely determined by national self-interest and a will to harmonize domestic progress between neighbors.

But now there are signs that a true weighing of national with international interest is beginning. Examples can be found in the European Economic Community (EEC), bilaterally in North America, and in the Economic Commission for Europe (ECE). Until 1983, the EEC generally made proposals to its member states. But now Britain, the Federal Republic of Germany, France, and others are themselves making substantive proposals for multilateral consideration on air and water pollution as well as transfrontier shipments of waste (47). The 1983 German initiative on acid rain is the best example, for it forces a clear linkage between domestic and international policies and squarely inserts environmental issues on the diplomatic agenda. What must follow is an apportionment of the substantial costs involved in air pollution control among countries. In effect, Italy has to pay for damage to German forests, the United Kingdom for damage to Scandinavian forests, and so on. If this linkage is achieved, the European Community will have moved forward from a position of harmonizing national environmental regulations designed for the benefit of each member state's economy to one in which the wider European economy (and that of countries outside the EEC) is to the fore. It will be a slow and difficult process.

The Bonn Communiqué also called for greater integration of resource management and environmental policies with other policies. On pollution control, countries such as the Netherlands, Sweden, and the United States are trying to correct the inefficiencies of dealing with individual problems in separate programs. "This approach," says the OECD, "may only result in moving a pollutant from one medium (such as air) to another (water and land). The problem is not eliminated but just moved from one place to another, and in some cases may create a greater risk in the new location than in the old" (48). The Netherlands has a new statute requiring coordinated licensing procedures and plans to "integrate all the environmental laws with land use planning at the provincial level." Japan, the Federal Republic of Germany, and the Netherlands all have programs to address "soil pollution," which deal with pollutants regardless of source—from the air, in the water, or through waste disposal.

Attempts to integrate environmental protection with other governmental programs are not confined to pollution control. In France, Sweden, and the Federal Republic of Germany, industrial inspections and audits may now combine environmental protection with occupational health and safety. In the United States, the agencies responsible for pollution control, food and drug safety, occupational health, and consumer protection have attempted to coordinate many of the health protection provisions of their individual mandates. In resource conservation, there is a growing employment of complex "multiple-use" policies that recognize the many functions a single piece of land may serve, such as commercial timber production, wildlife habitat, soil conservation, hydrologic regulation, and recreation (49).

Finally, the Bonn Communiqué reflected the current political context when it talked of harnessing both the mechanisms of governmental vigilance and the disciplines of the market to solve environmental problems. The utility of the "polluter pays" principle was highlighted. Background material, based on the conclusions of the OECD Environment and Economics Conference of 1984, stressed that environmental regulation need not have a negative impact on macroeconomic performance. Analyses presented at the 1984 meeting demonstrated that net macroeconomic effects of environmental controls are very small for those economies studied (Finland, France, the Netherlands, Norway, and the United States) (50). The papers for that conference show how far economic evaluation of environmental policies in the OECD countries has come. The arguments for and against different modes of control, the costs of different standards, and the array of economic instruments available are laid out, and the impacts in terms of employment, productivity, inflation, and trade analyzed (51).

International Agreements

Environmental problems have been handled at the local level for almost as long as human society has existed. By contrast, international attention is relatively recent, and attempts to achieve it in a systematic way have hardly reached beyond the stage of infancy (52).

The UNEP "Register of International Treaties and Other Agreements in the Field of the Environment" lists a total of 108 texts, including only two items approved earlier than 1939 (53). A more comprehensive register lists 257 relevant multilateral treaties for the protection of the environment that were signed before 1978. Of these treaties only 10 were signed before the end of 1939 (54).

The growth in the number of environmental treaties since the mid-1950s can be seen in Table 11.3. Table 11.4 shows a selection, drawn up by OECD, of the most recent and important conventions, showing the dates of signature and of entry into force upon ratification.

The most recent international agreement, the Global Convention on the Protection of the Ozone Layer, was signed March 22, 1985, by 20 countries and the EEC. For the first time in such an agreement, the Convention aims at *anticipating* a problem by calling for cooperation in research and monitoring, information exchange, and,

Table 11.3 International Agreements on the Environment, 1968–1983

Year	Number of Agreements
1868-99	2
1900-10	1
1911-19	0
1920-29	4
1930-39	3
1940-44	6
1945-49	27
1950-54	17
1955-59	38
1960-64	48
1965-69	44
1970-74	49
1975-79	39
1980-83	20

Source: Haigh. 1985. Reference 52

Table 11.4 International Legal Instruments Concerning the Environment[a]

No.	Purpose of Regulation	Type of Regulation[b]	Place and date	Entry into force
Sea pollution				
1	Limitation of liability of owners of sea-going ships	Conv	Brussels. 1957	5/31/68
2	Prevention of marine pollution by ships and aircraft	Conv	Oslo. 1972	4/7/74
3	Prevention of marine pollution by dumping of wastes	Conv	London, Mexico. 1972	8/30/75
4	Prevention of pollution from ships (MARPOL)	Conv	London. 1973	10/2/83
5	Protocol to No. 4 (segregated ballast)	Prot	London. 1978	10/2/83
6	Marine environment of the Baltic Sea	Conv	Helsinki. 1974	5/3/80
7	Prevention of marine pollution from land-based sources	Conv	Paris. 1974	5/6/78
8	Protection of Mediterranean Sea	Conv	Barcelona. 1976	2/12/78
9	Protocol to No. 8 (dumping from ships and aircraft)	Prot	Barcelona. 1976	2/12/78
10	Protocol to No. 8 (protection against land-based sources)	Prot	Athens. 1980	5/17/80
11	Protocol to No. 8 (pollution by oil. cooperation in emergency cases)	Prot	Barcelona. 1976	2/12/78
12	Limitation of liability for maritime claims	Conv	London, 1976	Pending
13	Prevention of pollution of the sea by oil[d]	Conv	London. 1954[c]	7/26/58
14	Pollution of the North Sea by oil[e]	Agr	Bonn. 1969	8/9/69
15	Civil liability for oil pollution damage	Conv	Brussels. 1969	6/19/75
16	Intervention on the High Seas	Conv	Brussels. 1969	5/6/75
17	Protocol to No. 16 (substances other than oil)	Prot	London. 1973	Pending
18	Protocol to No. 16 (CLC)	Prot	London. 1976	4/8/81
19	Cooperation against pollution of the sea	Agr	Copenhagen. 1971	10/16/71
20	International fund for compensation (oil pollution damage)[f]	Conv	Brussels. 1971	10/16/78
21	Civil liability for oil pollution damage-exploration of seabed mineral resources	Conv	London. 1977	Pending
22	Law of the Sea	Conv	Montego Bay, New York. 1982	Pending
23	Protection and development of the Wider Caribbean region	Conv	Cartagena, Colombia. 1983	Pending
Nuclear				
24	Third party liability for nuclear energy	Conv	Paris. 1960	4/1/68

Notes:
a. Signed or ratified by at least four OECD countries.
b. Agr. = Agreement. Conv. = Convention. Prot. = Protocol.
c. Renounced by several countries in 1983 and 1984.
d. Four amendments (London).
e. One amendment (Bonn. 1983).
f. FUND protocol. 1984.
g. Two supplements (Bonn, 1976).
h. One supplement.
Source: Organization for Economic Co-operation and Development (OECD). *OECD Environmental Data Compendium 1985* (OECD. Paris 1985). pp. 275-77.

eventually, for a protocol to control emissions of chloroflurocarbons, now considered by scientists to pose the greatest threat to the ozone layer and also contribute to the greenhouse effect. (See Chapter 10, "Atmosphere and Climate," Recent Developments.)

International law has developed rapidly as the planet has shrunk, since it is the only assured way of making nation states act in concert to overcome problems. Information exchange, conference pronouncements, and setting a good example are all parts of the process, but they cannot substitute for a body of law.

Yet the effectiveness of these international instruments varies widely. As conventions and treaties have had to deal with increasingly complex problems, their contents have become less precise and their effectiveness less predictable. Moreover, enforcement usually depends on the degree of general convergence of interests among the contracting parties. The more heterogeneous the contracting parties, the less precise and constraining the contents, and the less likely it is that they will be effectively enforced (55).

A good example of this phenomenon is the Convention on Long Range Transboundary Air Pollution prepared by the ECE, signed in 1979. The text is modeled on a prior convention signed by the members of the Nordic Council. In a comparison of the two conventions, it is striking how the greater number and variety of contracting parties have led to a significant reduction in the precision of

No.	Purpose of Regulation	Type of Regulation[b]	Place and date	Entry into force
25	Protocol to No. 24	Prot.	Paris, 1964	4/1/68
26	Supplementary to No. 24	Conv.	Brussels, 1963	12/4/74
27	Liability of operators of nuclear ships	Conv.	Brussels, 1962	
28	Banning nuclear weapon tests in the atmosphere, outer space, and under water	Treaty	Moscow, 1963	10/10/63
29	Prohibition of nuclear weapons on the seabed, oceanfloor and sub-soil	Treaty	London, Moscow, Washington, 1971	5/18/72
30	Civil liability on maritime carriage of nuclear material	Conv.	Brussels, 1971	7/15/75
Fauna and flora				
31	Preservation of fauna and flora	Conv.	London, 1933	11/8/33
32	Establishment of the European Mediterranean Plant Prot. Org.	Conv.	Paris, 1951	4/18/51
33	Conservation of the living resources of the SE Atlantic	Conv.	Rome, 1969	10/24/71
34	Wetlands; waterfowl habitat	Conv.	Ramsar, Iran, 1971	2/2/71
35	Protection of world cultural and natural heritage	Conv.	Paris, 1972	11/23/72
36	Antarctic seals	Conv.	London, 1972	11/23/72
37	Polar bears	Agr.	Olso, 1973	5/26/76
38	Fishing and conservation of the Baltic Sea	Conv.	Gdansk, 1973	7/28/74
39	International trade in endangered species	Conv.	Washington, 1973	7/1/75
40	European wildlife	Conv.	Berne, 1979	6/1/82
41	Migratory species	Conv.	Bonn, 1979	Pending
42	Antarctic marine living resources	Conv.	Canberra, 1980	4/7/82
Rhine pollution				
43	Protection of the Rhine against pollution[g]	Agr.	Bonn, 1963	5/1/65
44	Rhine choride pollution[h]	Conv.	Bonn, 1976	Pending
45	Restriction of use of detergents	Agr.	Strasbourg, 1968	2/16/71
Miscellaneous				
46	Damage caused by space objects	Conv.	London, Moscow, Washington, 1972	8/17/72
47	Nordic environmental protection	Conv.	Stockholm, 1974	10/5/76
48	Prohibition of military environmental modification techniques	Conv.	New York, 1977	10/5/76
49	Long range air pollution	Conv.	Geneva, 1979	3/16/83
50	Transfrontier co-operation	Conv.	Madrid, 1980	12/22/81

the final text, although perhaps it is too soon to say whether the larger number of parties to the ECE convention—all of which must be involved if the convention is to achieve its objectives—can ultimately work together (56).

A major difficulty in making international law is the gap between what is agreed to in negotiation and what is subsequently acceptable to national parliaments. The best known recent example in the environmental field was the initial failure of the convention for reducing chloride pollution of the Rhine, signed in 1976. The text was so specific in its terms and so constraining on the signatories that the French National Assembly refused to agree to its ratification (57).

The road between a sound negotiated text and effective action is long and tortuous. Most conventions specify the number of ratifications that are required before a convention enters into force, and even when in force it is only effective in those states that have ratified. Ratification is a national matter; other countries cannot compel a state to ratify. The states that have both signed and ratified must then take the necessary legal and administrative steps to ensure that the ends specified in the convention are achieved.

Some measures in international law create new organizations, a process that is sometimes only the beginning of a whole new set of difficulties. (See Box 11.2.) Given the lack of policing and verification of international agreements, the difficulty of incorporating the texts into national laws, and the freedom of governments to interpret provisions as they see fit, it is easy to see why new environmental law is not always synonymous with progress. Sometimes, because of the apparent advance, the reverse is even true: "Out of sight, into law and out of mind."

THE LARGER CONTEXT

Many actors other than those directly responsible for resource and environmental management have a great deal to do with the success or failure of the work of those directly involved. Public support and participation at the local level are crucial; so, ultimately, is a willing attitude in the business sector that recognizes its self-interest in sound environmental management. On the other hand, for many developing countries, the bilateral and multilateral assistance agencies can make a major difference. Bad policies—in terms of sustainable development—can send billions of dollars into counterproductive programs.

Here we briefly review the activities of some of those groups whose attitudes and actions strongly affect environmental outcomes. Subsequent editions of *World Resources* will review other diverse factors that determine the larger context, including: science and engineering, from basic research to new technologies; management of the international debt crisis; trade and protectionism; and the role of women.

Citizen Efforts and Public Support

Within the OECD nations, public support for environmental improvement—even at the expense of economic growth—remains surprisingly strong. (See Fig. 11.1.) Only about one quarter of the people are willing to see the environment suffer in order to secure economic growth; in Japan, even fewer. Where public opinion polls have asked the same questions over many years, the majority favoring stronger programs has grown steadily, despite ever-tightening budgets or, as in the United States, hostile administrations.

The recent rapid growth in citizens' groups dedicated to the environment and related issues should therefore be no surprise, though its dimensions are striking. The history of citizen concern with the environment goes back to the last century and many of the NGOs now involved are well over 50 years old. But since the late 1960s the number has exploded. More than 3,000 NGOs are now listed with the Environment Liaison Center (ELC) in Nairobi, a clearinghouse for environmental NGO activity.

The major feature of the citizen-based organizations for the environment is their remarkable diversity. Organizations reflect the global range of political and religious opinion, the salient local issues, and countless modes of working. It is hopeless to generalize, although several valuable national and regional surveys exist (58,59).

The sheer volume of reports, lawsuits, field projects, research, rallies, and press notices generated by NGOs has tended to overwhelm the bureaucrat. Indeed, there is plenty of anecdotal evidence to suggest that administrators have a deepseated dislike of the tangle of NGOs, despite the fact that in many ways it is the NGOs who make the government worker's life possible in political terms.

Most NGOs are local and focused on the immediate problems of day-to-day survival, the quality of the local environment, and community needs. Their activities are crucial: from tree planting, family planning work, wildlife and habitat conservation, to monitoring and forcing the clean-up of pollution sources and hazardous waste dumps. And the world over, they protest against the status quo. Countless organizations are not only questioning how we should live with respect to natural resource constraints, but are the mainspring of change.

A series of publications capturing some of this diversity in the Third World was the product of a major gathering of "grass roots NGOs" held in New Delhi in February, 1984 (60). The overriding message of the 1,000-plus local projects reviewed in the process was that, at the community level, environment and development concerns are so closely linked that it is somewhat academic to separate them. Survival for the rural and urban poor is so dependent upon their immediate environs that its custodianship is a prerequisite to breaking out of the cycle of poverty.

This linkage of environment, development and, to a lesser extent, population groups, which grows out of community-based development in the Third World, is also beginning to characterize groups in the developed countries. In effect, the traditional environmental lobby that grew out of the conservationist tradition is adopting a wider focus. The trend is not without some pain as the leaders of the conservation movement struggle to keep

Box 11.2 The International Tropical Timber Agreement

In early 1985, the International Tropical Timber Agreement (ITTA) came into force after a decade of negotiation between timber consumers and producers, and a major international campaign to secure ratifications. It is primarily a trade agreement promoted by the United Nations Commission for Trade and Development (UNCTAD), but unlike other such agreements it envisages the sustainable development and environmentally sound management of the commodity it seeks to regulate. Such management is vital if the tropical forests are to survive. (See Chapter 5, "Forests and Rangelands.")

What has happened since is all too typical of the international system and illustrates the real difficulties of forging cooperative policies from divergent economic interests, even when agreement exists on paper.

The new timber organization met once in July and again in November 1985 in Geneva. Each time delegates hoped that the basic organizational questions of headquarters' location and choice of executive director could be settled, so that the business of forest management could begin. But, on each occasion, the unwieldy politics typical of international commodity agreements got in the way.

Japan, importer of 40 percent of all traded tropical timber, insisted that the headquarters be in Yokohama. The North American and European group of importers preferred Amsterdam. Asian timber exporters, chief among them Malaysia and Indonesia, wanted Jakarta, and Latin American producers favored Rio de Janeiro.

Each location had its supporters from among the 37 ITTA members, but none managed to gain a simple majority of the distributed votes. Votes are allocated by means of a complex formula, with producers dividing 1,000 votes according to the export value of their timber trade, and the area of forest they possess. Thus Latin America, which has only 7 percent of the tropical timber trade, receives additional votes because it has 70 percent of the world's tropical forests.

Each consumer nation gets 10 votes when it joins, plus additional votes calculated according to the volume of its timber imports. Japan, with 398, has more votes than any other single consumer nation, and needs the support of only a few other countries to swing the balloting its way. Instrumental in the process of creating the timber agreement, the Japanese want to play a major role in the organization. But the other producer and consumer blocks appear equally committed to ensuring that their interests are well served within the ITTA. At its most recent meeting, the council resorted to secret balloting, a procedure that UNCTAD, in its caretaker role in many sensitive trade negotiations, has not found necessary since 1972. Even when Latin American producer nations withdrew Rio de Janeiro as a proposed headquarters site, the deadlock could not be resolved.

Though interest in the timber agreement and in the problems of deforestation still runs high, time is running out for ITTA. To date, its administrative expenses have been met by a $270,000 special advance from the U.N. General Assembly. This money has been used to hold the Geneva meetings, but is only a loan. ITTA members will have to come up with funds to pay back the loan, and to finance their next meeting.

an eye on their past concerns. But environment, as far as the citizen NGOs are concerned, has moved a long way from pandas and pollution control.

Similarly, "development" NGOs are increasingly recognizing the environmental component in their work and are beginning to promote an environmental message in their fundraising and opinion-forming activities. For example, the Swedish Red Cross and Earthscan recently published *Natural Disasters: Acts of God or Acts of Man?* investigating the degree to which environmental destruction from man's activities is the real cause of major floods, famines, and other "natural" disasters (61). The 1985 Global Meeting on Environment and Development, described earlier, included a broad range of development groups such as OXFAM, and the International Coalition for Development Action (ICDA) as well as the traditional environmental groups.

At the national level the thrust of environmental organizations is becoming more political. But how this manifests itself in terms of political parties varies, depending in part upon the voting system that applies. Thus in the Federal Republic of Germany, Holland, and Belgium, where there is a system of proportional representation, "green" parties have political force. To varying degrees, the major political parties in many countries, including Canada, New Zealand, the United Kingdom, and the United States are influenced by the environmental movement's ever-expanding agenda. This influence extends from the village green to the reform of the European Common Agriculture Agenda, from wood stoves to nuclear power, and from aid projects to international debt.

Business and Industry

The first decade of the environmental movement was marked in some places by confrontation between business and NGOs on almost every issue. While this posture persists, it is slowly giving way to a recognition on both sides that cooperation can accomplish more, with less delay for business activities, and at less cost (62). The new relationship comes from greater familiarity with the issues on the part of the business sector and the experience of a growing number of firms that good environmental practice is not prohibitively expensive, indeed that it may occasionally even improve the bottom line. On environmentalists' part, there is a new maturity and a recognition of business' immense influence—because of the size of investment and lending—on the futures of the developing countries. (See Table 11.5.)

Business' position, at least at the rhetorical level, was set out at WICEM. But who is bridging the gap between industrial activity and environmental needs? There are a few bridging institutions such as the UNEP Industry Office in Paris and the International Environmental and Development Service (IEDS), established in 1983 by the World Environmental Center (WEC). On the recipient government's request, IEDS supplies pollution-control experts from industry free of charge to provide technical advice. Industry volunteers specialists; U.S. AID pays their expenses. It is an innovative and effective program, but small compared to the need.

Another bridging initiative, UNEP's report on WICEM noted, was the 1984 international conference on the role of multinational corporations in developing countries, attended by corporate and industry association executives, developing country environmental officials, and other experts. This diverse group's conclusions appeared in 1985 as *Guidelines for Growth*, a set of commendable recommendations for host governments and corporations alike. Unfortunately, some of these recommendations, while perfectly reasonable, are out of reach of some developing country governments. For example, the report

Table 11.5 Total Net Receipts of Developing Countries From All Sources, 1970–83
(billions of constant 1982 US dollars)

	1970	1975	1976	1977	1978	1979	1980	1981	1982	1983
Official Development Assistance (ODA):	**21.10**	**30.23**	**28.97**	**27.59**	**31.70**	**32.68**	**35.34**	**36.48**	**34.74**	**33.82**
Bilateral	18.30	24.44	23.36	21.16	24.83	26.24	28.00	28.72	27.23	26.25
Multilateral agencies	2.79	5.78	5.61	6.43	6.88	6.44	7.34	7.76	7.51	7.54
Grants by private voluntary agencies	**2.24**	**2.02**	**1.96**	**1.98**	**1.89**	**2.01**	**2.28**	**1.98**	**2.31**	**2.21**
Non-concessional flows	**28.59**	**51.67**	**54.85**	**58.89**	**65.39**	**53.83**	**55.93**	**68.94**	**60.36**	**63.23**
Official or officially supported:	10.34	15.86	19.30	20.92	21.49	18.98	23.02	21.67	21.99	19.70
Private export credits (DAC)[a]	5.46	6.66	9.77	11.77	11.10	9.13	10.48	11.06	7.09	5.53
Official export credits (DAC)	1.54	1.81	2.01	1.92	2.54	1.79	2.32	1.97	2.66	2.11
Multilateral	1.85	3.81	3.68	3.58	3.53	4.29	4.57	5.59	6.61	7.03
Other official and private flows (DAC)	0.65	1.13	1.16	0.84	1.56	1.18	2.11	1.92	2.63	(3.02)
Other donors[b]	0.84	2.45	2.68	2.81	2.76	2.59	3.53	1.13	3.00	(2.01)
Private:	18.25	35.81	35.55	37.98	43.90	34.85	32.91	47.28	38.37	44.52
Direct investment	9.63	17.11	12.04	13.08	13.26	13.85	9.93	16.87	11.86	7.84
Bank sector[c]	7.83	18.07	21.74	20.64	26.17	20.30	21.68	29.35	26.00	36.18[d]
Bond lending	0.78	0.63	1.77	4.26	4.47	0.70	1.30	1.06	0.51	0.50
Total receipts	**51.93**	**83.92**	**85.78**	**88.47**	**98.98**	**88.52**	**93.45**	**107.40**	**97.41**	**100.25**
Sources of ODA to Developing Countries and Multilateral Agencies *(percent)*										
DAC countries	83	63	62	66	66	69	69	68	75	76
OPEC countries	5	28	29	25	26	23	24	23	16	15
CMEA[e] and other countries	12	9	9	9	8	8	7	9	9	9
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Notes:
a. Development Assistance Committee of OECD.
b. Other official flows from OPEC countries, Luxembourg (up to and including 1981), Spain, and Yugoslavia.
c. Excluding (i) bond lending and (ii) export credits extended by banks which are included under private export credits. Including loans by branches of OECD banks located in offshore centers, and for 1980, 1981, and 1982 participation of non-OECD banks in international syndicates.
d. The sharp rise in 1983 reflects debt-rescheduling arrangements, not a real increase in financing.
e. Council for Mutual Economic Assistance (CMEA).
Source: Organization for Economic Co-operation and Development (OECD), *Development Co-operation, 1984 Review* (OECD, Paris, 1984), p. 65.

notes that "delays, uncertainty, and unpredictable changes in environmental regulations do discourage investors, and should be avoided" (63). While unarguable, the recommendation is nonetheless irrelevant to a country with little or no environmental policy or one that undergoes regular political coups.

As it is for so many government administrators, the lack of reliable information is a real constraint to progress in the private sector. A 1984 U.S. Council on Environmental Quality survey of 45 large U.S. corporations concluded that corporations urgently need more international data and believe that the government's natural resource forecasts are not credible. Government's data, say business experts, are not up to date, although they are, nonetheless, business' principal source of information (64). Nearly all of those surveyed (96 percent) favored the creation of an international clearinghouse for natural resource information and improvement in the credibility of government natural resource forecasts.

United Nations Environment Program (UNEP)

Since its creation following the 1972 Stockholm conference, UNEP has been the international agency charged with spreading sound environmental policies inside and beyond the U.N. system. Over the years, as more and more countries have taken on environmental issues as a priority, they have turned to UNEP for technical advice, support and coordination.

But this tiny "catalytic" agency is not in a position to respond fully. With a small and politically vulnerable annual budget of $30 million, and the power to convince but not to coerce, UNEP is a David confronting a Goliath of issues. While it has been called "the environmental conscience of the U.N. system" and the source of many important initiatives, contributions to UNEP's budget are voluntary, unlike the official U.N. "specialized agencies" such as the World Health Organization. It is charged only with coordinating the environmental activities of other U.N. agencies and international organizations, and encouraging national programs. And with a staff of about 160, it is dwarfed by the vast U.N. system. Though symbolically important, UNEP's location in Nairobi has not improved its accessibility or efficiency.

UNEP's answer to its mandate to coordinate the environmental activities of the rest of the United Nations is a device known as the "system-wide medium-term environmental plan" (SWMTEP). As the name hints, it is a slow and cumbersome means of producing consensus. At UNEP's Governing Council meetings, now held every two years, many nations, large and small, show unwillingness to commit secure levels of funding, while demanding an elaborate program of work. About one third of UNEP's operating budget has come from the United States, where it is the subject of an annual political struggle.

With its limited budget, UNEP depends on a small professional staff to understand, coordinate, and report on the sea of environment related activities throughout the international system. Staff turn-over has been high in many important areas (65). The program cannot criticize or praise member countries for their environmental actions, making it difficult to focus public attention on the best and the worst situations and policies.

In many ways it is a hopeless task. Nevertheless, UNEP has some solid achievements to its credit. It has helped catalyze a number of important initiatives, many of them described in this volume, including the World Conservation Strategy, the Regional Seas Program, WICEM, and environmental work by the multilateral development agencies and banks. It has raised public awareness by inserting the environmental dimension in dozens of other U.N. programs. Perhaps most significant has been its contribution in the fields of environmental data collection and assessment through GEMS, GRID, and other efforts.

International Assistance—Multilateral Flows

The World Bank is the largest single source of external development assistance for many poor countries. Because of its size and its large professional staff—more than 3,000—it is also often the policy leader in development assistance. In 1978 the World Bank's environmental practices received a qualified endorsement in a study of international development agencies called *Banking on the Biosphere?* by the International Institute for Environment and Development (IIED) (66). A year later, the Bank's environmental office, together with UNEP, was instrumental in formulating the Declaration of Environmental Policy and Procedures and in forming the Committee of International Development Institutions on the Environment (CIDIE). CIDIE has had a series of lack-luster meetings every year since, involving a dozen or so of the multilateral development agencies and regional development banks (67).

Yet in recent years the Bank has been the target of widespread, international pressure to become more ecologically sophisticated and responsible. It has been urged to expand its Office of Environmental and Scientific Affairs because that office has only a small voice in decisions on which projects are to be financed. The office is also understaffed and underfunded to review the hundreds of projects amounting to $14 billion that the Bank funds annually in 80 different countries. Because of the sheer size of World Bank projects, which average about $10 million, the Bank's activities are inherently more likely to have environmental side-effects than those of small agencies.

For example, World Bank ecologist Robert Goodland characterizes much of the criticism directed at Bank-funded water projects: These large capital-intensive projects, which have been a major focus of Bank lending, destroy natural environments and rob inhabitants of the resources their watersheds provide. Goodland noted that major water projects can cause "massive damage" such as the "failure of involuntary human resettlement, irreversible loss of wildlife and genetic diversity, loss of agricultural and forest land by inundation, reduction of site-related soil fertility, intensified erosion below the dam, sedimentation into the reservoir, induced seismicity, and an increase in water-related diseases such as malaria and schistosomiasis" (68).

In 1984 the Bank set out its environmental policies, procedures and requirements (69,70). These documents attach great importance to environmental questions within the project cycle and in the economic and sector work of the Bank. But there is an acute shortage of environmental specialists on the Bank's large staff (71), and environmental considerations are not routinely considered early and thoroughly enough in the design of individual projects (72). In testimony before a U.S. Senate subcommittee, the U.S. Treasury pointed to another problem. It suggested that all the multilateral banks tend to overemphasize the quantity rather than the quality of lending: "We suspect that the problems encountered in the environmental aspects of projects may be an instance of such an overemphasis. If environmental considerations threaten expeditious project processing, the environment is assigned low priority and is left to be dealt with later" (73). In effect, under current procedures, the desire to accelerate development assistance is pitted against environmental and social considerations. The conflict is not inherent; improved procedures would resolve much of the problem. However, because of the vastness and diversity of the Bank's lending, it is no mean task to determine how to make these changes. Still, indications are that the Bank's lending is more rigorously scrutinized than that of the regional banks for Asia, Latin America, and Africa, and the Bank is currently attempting to identify ways to better integrate resource and environmental concerns into its programs.

While the capacity of the multilateral agencies to anticipate the environmental consequences of their project lending is still inadequate, lending for projects specifically designed to improve or rehabilitate the environment has increased. Also, the World Bank is a leader in the effort to slow tropical deforestation (74), and it has highlighted the need to pay greater attention to environmental and resource constraints in developing a new lending strategy for sub-Saharan Africa (75).

Bilateral Assistance

Most bilateral aid agencies have expressed the right sentiments about the importance of environmental problems. However, many would go on to point out that they *respond* to requests for assistance and do not have the freedom to lay down the rules. They would also emphasize that the broader context of international development is more important than environmental concerns. Political instability, lack of human resources, corruption, and the international economic setting are the principal problems, and not the environmental or social procedures they follow. Yet there is room for progress.

A recent review by IIED of the environmental procedures and practices of the national aid agencies of Canada, the United States, the Federal Republic of Germany, the United Kingdom, the Netherlands, and Sweden, concluded that U.S. AID was the only agency with systematic, enforceable procedures backed by the staff necessary to carry them out (76). Since then, the Nordic, Dutch, and West German agencies have made some progress on the policy level, have begun to make some money available for environmental programs, and have produced guidelines or checklists to guide their programs (77,78,79).

However, developing the language is one thing; putting the ideas to use another. A subsequent study of the guidelines drafted and used by the major development agencies concluded that there was little evidence of the systematic application of the existing texts (80). (U.S. AID has gone beyond guidelines and adopted formal regulations. The study does not suggest that these regulations are not being followed.) Some agencies never put some environmental guidelines into operation because their purpose was only to improve public relations or to provide educational material to the development community in general. In other cases staff of agencies do not use guidelines systematically because they are too general or incompatible with real tasks and problems. In many cases the agencies do not organize the appropriate training, nor establish any institutional penalties for failing to use the guidelines.

Most of the major bilateral assistance agencies would probably accept the following environmental objectives:

- To ensure that environmental planning is not left out of development planning or the aid project cycle;
- To raise indigenous environmental/natural resource management capability to enable such planning to occur;
- To gather sufficient hard data of an environmental kind (taxonomic, ecological, geological, etc.) for the same ends;
- To encourage public education, particularly in the developing countries, since judgments and policies must increasingly be made at the country level;
- To concentrate financial and human resources on systems and sectors that are particularly at risk: be they deserts, watersheds, moist forests, the urban environment, renewable energy supply, or sustainable agriculture/forestry.

There would be argument over environmental techniques within the aid process, with some, for example, preferring formal impact assessments, others a looser review. Priorities would differ among countries. Guidelines would be employed (or not) as indicated above. In a few cases, a body of "law" would help ensure that environmental considerations are addressed, as in the case of U.S. AID and the European Development Fund. The Lome III convention among the African, Caribbean, and Pacific States, and the European Community and its member states contains general articles on environment as well as specific items on reforestation, desertification, and sustainable yield management (81). But, sadly, there is little evidence that the funding, staffing, or will is there to see these sound policies put into effect.

CONCLUSION

A review such as this cannot definitively answer the question whether the world's institutions are responding adequately to the environmental needs before them. Solid answers would require far more country-by-country data than exist today, and a volume as large as the one before you. Yet this preliminary survey does permit some conclusions. Environmental policy is more sophisticated and is being practiced more widely than ever before. Few if any governments any longer see conservation of natural resources as irrelevant to their economic goals. Most have taken steps, at least on paper, to protect their environments, and public support of such policies is strong (though little is known about public opinion on this subject in many parts of the world). Nevertheless, many of the tools for sound management are weak. In a great many countries, even where there is a political commitment and adequate legislation, implementation, enforcement, and monitoring are generally deficient. The reasons are an intimidating combination of inadequate financial resources, trained staff, technical capabilities, and reliable data.

Though domestic issues still pose formidable challenges—from soil erosion to toxic waste disposal—the environmental policy agenda is becoming increasingly crowded with issues that must be addressed on a regional or even global basis. In the cases of acid deposition and associated forms of transboundary air pollution, and of changes in the ozone layer, governments are taking the first tentative steps to find ways to address them. Still, however, the record of accomplishment of the more straightforward, traditional international agreements is weak. Finally, the course of economic development in the Third World is strongly influenced by external funds—from official sources of assistance and direct investment by the private sector—and here there is room for much needed progress if sound environment and resource management policies are to be widely achieved.

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12. Multiple Pollutants and Forest Decline

A specter is haunting Europe and North America—the specter of widespread forest decline. The mass mortality of trees observed across large areas of Central and Eastern Europe over the past five years seems to be accelerating. Europe's forests appear to be threatened by a mysterious and deadly combination of airborne pollutants and natural stresses, including climatic factors and pathogens. New evidence suggests that a similar process is undermining the health of North America's high elevation eastern coniferous forests. Despite the frenetic research programs launched over the past few years to discover the causes of *Waldsterben* (forest death)—the collective name given to this frightening collection of symptoms in West Germany—there is no scientific consensus as to its primary triggering agents. (See Table 12.1.) Sorting out the causal agents is among the most challenging scientific detective tasks of the century. Given the severity of the *Waldsterben* syndrome there is no time to lose in grappling with its causes and formulating effective control strategies.

The stakes are high. The future health and vigor of virtually every major species of conifer and broad-leafed tree in Europe are threatened, as well as some commercially important conifers in North America (1). Also at risk is the future of the multi-billion dollar forest industry, which provides jobs for 1.4 million people in the European Economic Community alone (700,000 in West Germany). The ultimate victims, however, may be forest ecosystems themselves, which may be gradually degraded and perhaps genetically impoverished by humankind's polluting activities.

The extent of destruction is staggering. Today, nearly 6 million hectares of forests have been affected by *Waldsterben* in just five countries: West Germany, Austria, Czechoslovakia, Poland and Yugoslavia (2). Extensive forest damage has also been reported in East Germany, Hungary, Rumania, the Netherlands, Belgium, France, Switzerland, Sweden, and the United States. It is said to be appearing in the Soviet Union (though to an unknown degree), as well as Great Britain, Spain, Italy, and Canada (3). (See Box 12.1.)

When the first signs of this unique disease phenomenon began to show up in the early 1970s on West German white fir (*Abies alba*, also called silver fir), forest researchers thought it might be similar to the white fir decline (*Tannensterben*) that had been periodically affecting fir forests in central Europe for the past 250 years (4). But, in the late 1970s the decline symptoms spread to Norway spruce (*Picea abies*) and by 1980 it was apparent that scientists were faced with an entirely new set of forest decline symptoms, some of which are unprecedented in the literature of forest diebacks and declines.

The fir and spruce forests were only the first to be affected. Scotch pine (*Pinus sylvestris*, called Scots pine in Europe) began to decline throughout its range in 1980, followed by European beech (*Fagus sylvatica*) (5). Now *Waldsterben* affects at least 11 species in Europe: four of the most important conifers including Norway spruce,

Table 12.1 The Common Symptoms of *Waldsterben*

Growth-Decreasing Symptoms:

- Discoloration and loss of foliar biomass (yellowing and browning of needles and leaves)
- Loss of feeder-root biomass, especially in conifers
- Decreased annual increment (width of growth rings)
- Premature senescence (aging) of older needles in conifers
- Increased susceptibility to secondary root and foliar pathogens
- Death of herbaceous vegetation beneath affected trees (all within the drip line of the canopy)
- Prodigious production of lichens on affected trees
- Death of affected trees

Abnormal-Growth Symptoms:

- Active shedding of needles and leaves while still green, with no indication of disease
- Shedding of whole green shoots, especially in spruce
- Formation of stork's nest crowns in young white fir
- Altered branching habit and greater than normal production of adventicious (out-of-place) shoots
- Altered morphology of leaves
- Altered allocation of photosynthate
- Excessive seed and cone production year after year
- Diseased trees show growth at top, not near bottom, with very brittle branches

Water-Stress Symptoms:

- Altered water balance
- Increased incidence of wet wood disease

Note: Table 12.2 compares these symptoms in European and North American forest declines and suggests possible causative agents.
Source: Schütt and Cowling, 1985, Reference 1.

Box 12.1. The Scorecard of European Destruction

Across the European continent and into southern Scandinavia the scourge of *Waldsterben* is spreading rapidly, like an uncontrolled cancer. At the end of 1985, forests had been stricken across at least 7 million hectares in 15 European countries (both East and West) (1).

WESTERN EUROPE AND SCANDINAVIA

1. West Germany is the most seriously affected country in Europe with 52–55 percent of its forests, covering nearly 4 million hectares, in various stages of decline and death. *Waldsterben* has devastated the Federal Republic's forests with alarming speed. In 1982, only 8 percent of the country's forests (not individual trees) showed signs of damage. By 1983 this figure had jumped to 34 percent, and in 1984 the Federal Ministry of Food, Agriculture and Forestry, reported that 50 percent of the forests were suffering. The 1985 survey showed a slight increase in destruction: nearly 55 percent of the forest stands were damaged. The worst affected areas are in the States (Lander) of Bavaria and Baden Wurttemberg (home of the Black Forest). Severe damage has also been reported for the Harz, Sauerland, and Eggegebirge mountain areas (2).

   The economic costs of *Waldsterben* are mounting up. In one estimate, West German timber and related industries are losing up to $509 million annually, and damages could go as high as $9–11 billion a year (3). The Union of German Forest Owners, however, calculates the eventual damage at nearly $1 billion a year if present trends continue (4).
2. Switzerland ranks second in damage (in Western Europe) after West Germany. In 1983, 8–14 percent of the country's total forested area was said to be affected by *Waldsterben*. By 1984 this figure had ballooned to a full third (33 percent) of Swiss forests, and 12 million sick trees (representing 14 percent of the total forest area) had to be felled. The worst affected areas are located in the southern alpine cantons of Grisons and Valais, where 50–60 percent of the trees are said to be severely affected (5).
3. Austria has also been badly hit by *Waldsterben*—16 percent of its forests covering 600,000 hectares are reported injured. Austrian authorities are concerned that the country could be stripped of 4.2 million cubic meters of timber a year at a cost of $160 million (6).
4. The Netherlands cataloged the extent of forest damage in December 1984. The survey included 2,800 sites covering an area of 281,000 hectares, or 85 percent of Dutch woodlands. The prognosis was grim: 40 percent showed signs of damage, but forestry officials claimed that about half the damaged trees could recover. Still, 8 percent of the country's forests were in the critical category (7).
5. France also suffers from *Waldsterben*. In mid-1985, the French Ministry of Environment put the total damage in the Vosges region of northeast France at 20 percent; 35,000 hectares were affected with 5,000 hectares in serious condition (8). However, long-term residents in the area claim the damage is more like 80 percent. Says Jean-Paul Ortscheidt, a naturalist from Vosges, "there are no healthy conifers on the forest floor" (9). Furthermore, it has been reported that fir trees throughout Alsace and the Donon Massif have been losing their needles at an unnatural rate for four years (10).
6. Belgium reports that 70 percent of the forests along the border with West Germany are damaged to one degree or another (11).
7. Denmark claims that trees covering 1,000 hectares in west Jutland are suffering from *Waldsterben*-like symptoms (12).
8. Sweden surveyed its southern forests in 1984 and found that 240 forest stands in 11 counties were showing symptoms of decline. The National Swedish Environment Protection Board puts the damage at 10 percent; in other words every 10th tree is injured (13).
9. Great Britain maintains that it has not been affected by *Waldsterben* and reports no official damage to forests. A 1984 survey by Britain's Forestry Commission, however, concluded that 6 percent of the spruce and 20 percent of the Scotch pines were suffering, but attributed the damage to "cold, windy, winter weather" (14). Swedish plant ecologist Bengt Nihlgård visited Britain in the summer of 1985 and reported seeing extensive damage to oak, beech, and ash. He told the *Guardian* newspaper that the symptoms of decline were identical to those in Central Europe (15).

EASTERN EUROPE AND THE SOVIET UNION

1. Czechoslovakia is the most seriously affected country in Eastern Europe. By 1980, 400,000 hectares of forests were reported damaged (16) and the figure now stands at between 500,000 and 1 million hectares, with 200,000–300,000 hectares said to be completely destroyed (17). A report issued by the Czechoslovak Academy of Sciences (CSAV) entitled "An Analysis of the Ecological Situation in Czechoslovakia" documents frightful damage over wide areas. More than 6,000 square kilometers of the Czech Lands—which constitute 60 percent of the country's land area—are permanently exposed to excessive concentrations of air pollutants; and 24 percent of the forests in this region are injured (18). The list of damage is horrific:
   - Norway spruce are reportedly dying in over 32,000 hectares of forests in the Giant Mountains.
   - Sixty percent of the trees in a 19,200 hectare-section of the Orlicke Hory Mountains were dead by 1980.
   - In the Ore Mountains (Krusne Hory Mountains) of Northwest Bohemia (near the borders with East and West Germany) the damage is so widespread that most of its 85,000 hectares of woodland will be dead by 1990, in just four years (19).

white fir, Scotch pine and European larch (*Larix decidua*) and seven of the most significant broad-leafed trees—European beech, silver birch (*Betula pendula*), European ash (*Fraxinus excelsior*), European alder (*Alnus glutinosa*), common maple (*Acer pseudoplatanus*) and two species of oak (*Quercus robur* and *Quercus petraea*) (6).

The new kind of forest decline observed in North America is distinct from European *Waldsterben*. The "New World" version affects only conifers with each species showing different symptoms. Scientists have investigated at least eight species in North America: white, loblolly, shortleaf, pitch, and slash pines, red spruce and balsam and Fraser firs (7). (For a comparison of the symptoms of *Waldsterben* in Europe and the new kind of forest decline in North America, see Table 12.2.).

The Federal Republic of Germany (West Germany) has established a *Waldsterben* survey procedure that involves four categories of damage. Every year since 1982, the various provincial governments have conducted a nationwide inventory of the country's forests, ranking them according to the amount of leaves or needles on the tree. It includes the following stages: 0) healthy, less than 10 percent loss of foliage; 1) slight, 11–25 percent loss of foliage; 2) moderate, 26–60 percent loss of foliage; 3) serious, over 60 percent loss of foliage; and 4) death. By this method the affected species can be assigned a damage category so that the advance or retreat of *Waldsterben* can be assessed every year for each species (8). (See Table 12.3.) Variations on this theme are used in other European countries in determining the health of forests and rating the damage.

Figure 12.1 shows the alarming progression of *Waldsterben* from 1983 to 1984 in the Federal Republic of Germany. White (silver) fir is the most seriously affected tree

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Czechoslovak scientists attribute the damage to heavy metal fallout, acid rain, and gaseous emissions of sulfur dioxide and ozone. The CSAV report predicted that over 50 percent of the country's woodlands would be injured and dying by the end of the century, if present trends continue (20).

2. Poland is said to be one of the world's most polluted countries (21). In the Upper Silesian Industrial Region (in Southwest Poland), around Krakow and in the Legnica-Glogow copper basin, forests covering 500,000 hectares—6 percent of the total—are reportedly affected by serious dieback, with 200,000 hectares already dead (22).
3. Yugoslavia reports 450,000 hectares of forests damaged, with 50,000 hectares on the critical list (23).
4. The German Democratic Republic (East Germany) does not officially report its forest decline problems. Nevertheless, scientific accounts published in 1980 estimated that at least 350,000 hectares, or 12 percent, of the country's forests were suffering from *Waldsterben* (24). However, recent evidence indicates that the extent of damage may be as high as 2.5 million hectares. The damage is particularly acute in the Erzgebirge Mountains near the Czech and West German border. East German scientists blame gaseous pollutants; namely sulfur dioxide, nitrogen oxides and ozone, in combination with acid rain (25).
5. Romania claims that at least 170,000 hectares of forests are damaged in the western part of the country (26).
6. Hungary reported in the summer of 1985 that 11 percent of its forests—covering 120,000 hectares, along the northern border with Czechoslovakia were injured (27). Over the past three years the damaged timber is estimated at 1.2 million cubic meters, worth more than 1 billion forints ($20 million). Winter damage has seriously affected 10,000 hectares of Scotch pines, which may have been predisposed by pollution. But Hungarian scientists are more alarmed about the increasingly critical condition of their oak forests, which account for 70 percent of the total damage (28). Initial studies have indicated that Hungary's younger oak forests are suffering from a 5 percent reduction in growth rates when compared to older stands. Forest specialists confirm that all kinds of trees besides oaks, are affected, including firs, pines, spruce, beech, and elm. A concerned government has earmarked half of the annual forestry budget of 15–20 million forints ($200,000–300,000) for research into the causes and remedies of forest decline (29).
7. The Soviet Union is known to be experiencing acid deposition over some 900,000 hectares in European Russia, but there are no confirmed reports of forest decline, except near the industrial town of Togliatti and along the Volga River (30). These declines may be due to entirely different factors.

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Table 12.2 Comparison of Symptoms and Possible Causes of Forest Declines in Europe and North America

Possible Causative Agent	Symptoms	Central Europe	Eastern North America
	Growth-decreasing symptoms:		
Foliar Leaching, Ozone, Drought	Yellowing of foliage from the lower to the upper and from the inner to the outer portion of branches—oldest tissues affected first	Observed mainly in white fir and Norway spruce at high elevation	Observed in white fir in the San Bernardino Mountains and recently in red spruce in New York and Vermont
Natural Stress, Abiotic and Biotic	Dying back from the top of trees—youngest tissues affected first	Common in oak and ash, less common in birch and beech	Conspicuous in red spruce, maple and oak declines; ash and birch diebacks
SO_2, Insect Pests, Drought	Increased transparency of crowns due to gradual loss of leaves but with leaves retained to the very top of the trees	Observed in Norway spruce, white fir, Scots pine, larch, beech, birch, oak, maple, ash, and alder	Observed only in the littleleaf disease of shortleaf pine and in the beech-bark disease
Fertilization	Losses of fine-root biomass and mycorrhizae (beneficial symbiosis between tree roots and soil fungi)	Common in white fir, Norway spruce and beech. Not studied in other species	Observed mainly in red spruce decline, birch dieback, and littleleaf disease
Chronic Ozone Chronic SO_2	Synchronized decrease in diameter growth without other visible symptoms	Not reported in Europe	Observed in pitch pine and shortleaf pine
Acute Ozone Acute SO_2 Foliar Fertilization	Synchronized decrease in diameter growth with other visible symptoms. May result in mortality	Studied mainly in Norway spruce, white fir, and beech. Not studied in other species	Observed in red spruce and Fraser fir mainly at high elevation
Heavy Metals, Nutrient Stress	Progressive decrease in diameter growth with other visible symptoms. May result in mortality	Studied mainly in Norway spruce, white fir and beech. Not studied in other species	Observed in ash and birch diebacks, some maple and oak declines, sweetgum blight, littleleaf disease, and pole blight
Heavy Metals, Organic Substances	Death of herbaceous vegetation beneath some affected trees	Observed in high elevation spruce and medium elevation beech forests	Not observed in North America
	Abnormal-growth symptoms:		
Organic Substances	Active casting off (abscission) of leaves and shoots while still green	Common in spruce, fir, beech, ash, larch, and Scots pine	Reported only rarely in North America in loblolly pine, red spruce, and Fraser fir
Organic Substances	Change in relative length of long shoots and short shoots	Common in beech	Reported only in the mycoplasma induced "yellow" of ash
Ozone	Concentration of leaves and needles at tips of branches in tufts or clumps	Common in oak and ash	Observed in nearly all decline of broad-leaved trees and in some conifers
Organic Substances	Change in size and shape of leaves	Common in beech and birch, occasionally in oak, spruce and Scotch pine	Common in white pine, littleleaf disease of shortleaf pine, and some maple and oak declines
Stress	Excessive production of adventitious shoots on branches	Common in Norway spruce, white fir, and larch	Observed recently for the first time in conifers. Common in maple and oak, ash, and birch
Stress, N Fertilization	Excessive production of seeds and cones	Common in spruce, fir, beech, and birch, often observed several years in a row	Observed in many stressed trees mainly one year at a time

Source: Bartuska et al., 1985 (Reference 21); Cowling, 1985 (Reference 20).

Table 12.3 West German Forest Damage Surveys, 1982–84

Tree Species	Millions of Hectares 1982	Millions of Hectares 1983	Millions of Hectares 1984	Percent of Forests Damaged 1982	Percent of Forests Damaged 1983	Percent of Forests Damaged 1984
Spruce	270	1 195	1 477	9	41	51
Pine	090	641	866	5	44	59
Fir	100	135	152	60	75	87
Beech	050	326	631	4	26	50
Oak	020	090	269	4	15	43
Others	032	161	303	4	17	31
Total	562	2 549	3 698	8	34	50

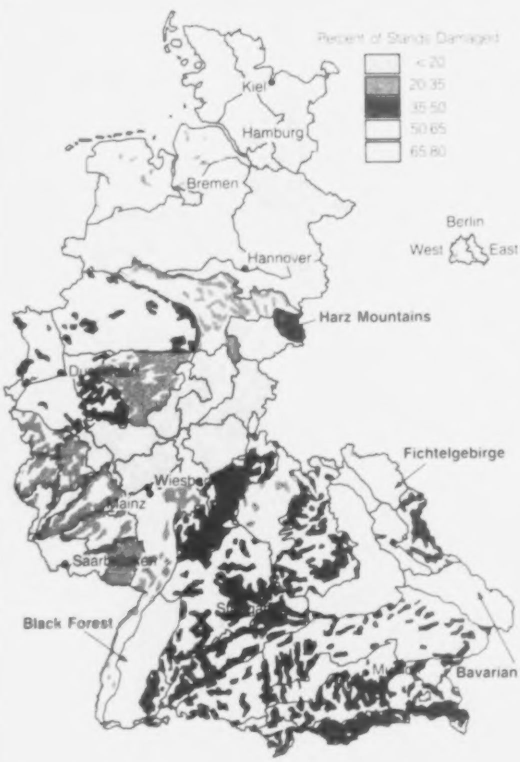
Note: Damaged area includes stages 1, 2, 3, and 4.
Source: West German Federal Ministry of Food, Agriculture and Forestry, 1984 (Reference 8).

species in West German forests, with 87 percent of its stands damaged and Scotch pine is not far behind with 59 percent of all stands affected. In trees 60 years or older the damage is most severe with 95 percent of all white fir, 73 percent of all Scotch pine and 82 percent of all Norway spruce stands showing visible decline symptoms (9).

Furthermore, the severity of the dieback in Europe is escalating as more trees move into the terminal stages of "decline". The 1985 forest survey in West Germany revealed that many trees that showed only mild damage (stages 1 or 2) in 1984 had moved into stages 3 and 4. For most species the period of time between the first symptoms of damage and the stage at which the tree has to be cut varies from a few weeks to three years (10).

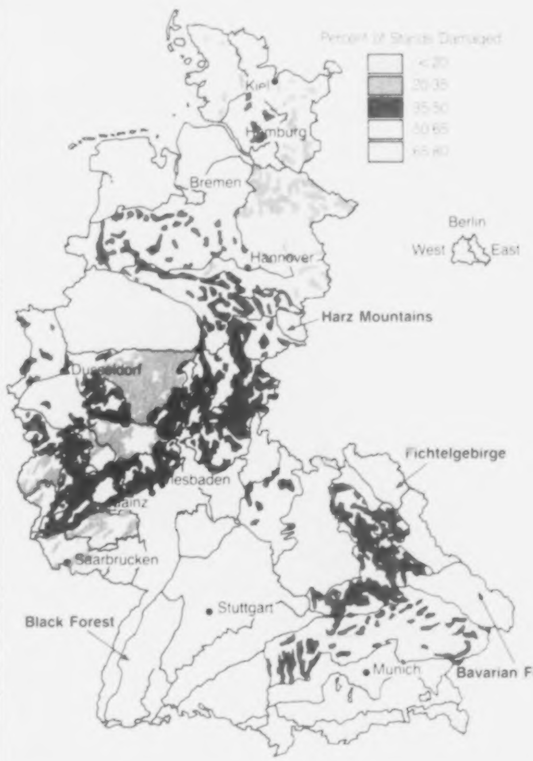
In the Black and Bavarian Forests of southwestern and southeastern Germany, respectively, *Waldsterben* is particularly acute. Both conifers and broad-leafed trees stand stripped of all foliage and some are covered with lichens. Dead, brittle branches litter the forest floor. Other trees, weakened from the "disease" and uprooted by winds, show stunted and deformed root systems. In some cases the fungus roots (mycorrhizae)—responsible for nutrient uptake—are very limited or completely absent. *Waldsterben* seems to affect every part of the tree's physiology. Among those trees still alive, many have lost 60 percent or more of their leaves and needles and will soon perish, finished off by frost, wind damage and insect attacks. Many of the stressed trees attempt to fight off death by shedding leaves and needles while still green, others produce masses of cones or seeds in efforts to reproduce. In parts of the Bavarian forest, even the vegetation beneath the drip line of the canopy is brown and lifeless. It's almost as if the entire ecosystem has been poisoned. As the forests go, so too does the wildlife. Noticeably fewer birds and animals inhabit some *Waldsterben* stricken forests. This same picture is repeating itself across at least

Figure 12.1A Forest Decline in the Federal Republic of Germany, 1983


Percent of Stands Damaged
<20
20-35
35-50
50-65
65-80
Kiel
Hamburg
Bremen
Hannover
Berlin
West
East
Harz Mountains
Fichtelgebirge
Black Forest
Bavarian Forest

Note: Shaded areas represent percent of stands damaged, including all tree species and damage classes 1 to 4.
Source: West German Federal Ministry of Food, Agriculture, and Forestry, 1984.

Figure 12.1B Forest Decline in the Federal Republic of Germany, 1984


Percent of Stands Damaged
<20
20-35
35-50
50-65
65-80
Kiel
Hamburg
Bremen
Hannover
Berlin
West
East
Harz Mountains
Dusseldorf
Wiesbaden
Mainz
Saarbrucken
Fichtelgebirge
Stuttgart
Black Forest
Munich
Bavarian Forest

Note: Shaded areas represent percent of stands damaged, including all tree species and damage classes 1 to 4.
Source: West German Federal Ministry of Food, Agriculture, and Forestry, 1984.

seven million hectares of forestlands in 15 European countries. (See Box 12.1.)

HISTORIC FOREST DECLINE

Of course, air pollution damage to forests is nothing new. As the Industrial Revolution gathered momentum in the latter part of the 19th Century, many point sources of pollution were responsible for high levels of atmospheric contaminants. Trees and other vegetation have been dying near metal smelters, chemical plants, refineries, and fossil fuel-fired power stations for the past one hundred years or more (11). Forests in Central and Eastern Europe have been suffering periodically from "smoke damage" since the middle of the 19th Century. The "smoke" usually consisted of a toxic concoction of sulfur dioxide, nitrogen oxides, and heavy metals, along with soot, ash, and dust from coal-fired industrial processes, metal smelters, and power plants. However, such damage was usually found close to heavily industrialized, urban areas; it was seldom generalized over entire regions (12).

In recent years the pattern of pollution in Eastern Europe has changed dramatically. Czechoslovakia, in particular, has become very heavily polluted (as documented by the Czechoslovak Academy of Sciences [CSAV]). (See Box 12.1.) Total gaseous emissions jumped from 3.6 million metric tons in 1960 to 7.3 million metric tons by 1980, an increase of more than 100 percent (13). The amount of sulfur dioxide generated in 1980 was 3.2 million metric tons, while 1.6 million metric tons of nitrogen oxides were also produced along with 500,000 metric tons of hydrocarbons (14). "As a result of these various facts," writes F. W. Carter, a geographer at University College, London, "Czechoslovakia is now among one of the most intensely air polluted countries in the world. On average, about eight metric tons of atmospheric pollutants per inhabitant are generated annually and in urban areas the average yearly solid particle emission reaches 500 metric tons per square kilometer (15)." Little wonder that the country's forests, not to mention human population, are under increasing stress from air pollution. The same is true for the heavily industrialized parts of Poland and East Germany, which are known to have large areas of "smoke" damaged forests. In an effort to combat the damage, Poland has been experimenting with pollution-resistant trees for the past 15–20 years.

Gaseous pollutants, like sulfur dioxide, hydrogen fluoride, and ozone, have played prominent roles in past declines, but their destructive effects have been relatively "localized," or limited to specific areas under continuous assault from airborne pollution. As early as 1910–11 damaged trees (mostly lodgepole pine and Douglas fir) were investigated in the Deerlodge National Forest located near the Washoe metal smelter at Anaconda, Montana (U.S.). They were found to be suffering, in part, from sulfur dioxide pollution, which retarded their growth (16). Similarly, ozone has damaged or killed thousands of ponderosa and Jeffrey pines in the San Bernardino Mountains east of Los Angeles, California, a city famous for its yellow-brown photochemical smog. A U.S. Forest Service survey carried out in 1969 revealed that some 1.3 million ponderosa pines growing on 405 square kilometers in the San Bernardino National Forest were stressed and dying (17). In areas with the highest ozone concentrations, timber yield was found to be reduced by 80 percent or more. Today, both ponderosa and Jeffrey pines have been seriously damaged or killed over wide areas in the San Bernardino Mountains, resulting in a markedly altered forest ecosystem.

However, natural stresses like drought, frost, and winter damage (called abiotic factors) along with biotic factors such as insect infestations, fungi, and other disease organisms have probably figured prominently in most large-scale forest declines of the past. Between 1871 and 1880, for example, red spruce forests from New York State to New Brunswick, Canada were devastated by what has since been attributed to a combination of drought conditions and insect attacks (18).

These earlier experiences have led some researchers to assign *Waldsterben* to natural causes, rather than the wide spectrum of anthropogenic pollutants now under investigation on both sides of the Atlantic. Dr. Otto Kandler of the Botanical Institute at the University of Munich believes that *Waldsterben* is due to a mysterious virus imported from Czechoslovakia. "There are several epidemics in our forests," says Kandler, "they are periodic with peaks and troughs. What we have now is the coincidence of several peaks in the old diseases, plus a new one" (19). So far the "virus" has yet to be identified or described in any detail and many researchers are skeptical of the idea that *Waldsterben* is just one more chapter in the familiar book of forest dieback. "We are faced with a very complex problem," says Dr. Claude Martin, Director of the World Wildlife Fund of Switzerland, and "it would be wrong to put forest death down to one cause. It is just as stupid to blame a virus as it would be to say that forests were dying only because people were driving their cars too fast. There are a multitude of factors leading to this situation and we are convinced air pollution is a major one."

The virus view ignores important clues that clearly separate *Waldsterben* from previous documented declines due to biotic or abiotic factors. Historically, most forest damage was limited to one or two agents, or a combination of several; in nearly every case there were visible "smoking pistols." Moreover, the damage was usually localized or, if regional, involved only a few species. Never before has such large-scale and rapidly spreading forest decline been observed affecting so many different species under such varied ecological conditions. Over the past 50 years there have been 19 major or minor regional forest declines in Europe and North America. Of these 19 reported declines, at least seven implicate air pollutants as a primary, or at least a contributory, cause (20). (See Table 12.4.) With one exception, all of the pollution-related declines developed (or at least were noticed) within the last eight years. Increasingly, the finger is being pointed at airborne chemical pollution as the major cause of forest decline and death (21).

DAMAGE TO FORESTS

Waldsterben is, by far, the most complicated and serious forest decline on record. Dr. Peter Schütt, Professor of Forest Botany and Pathology at the University of Munich and Dr. Ellis Cowling, Associate Dean for Research at the School of Forest Resources at North Carolina State University in Raleigh, have produced a comprehensive description of *Waldsterben* (22). The following features of the "disease" and its extent are noteworthy:

1. Visible symptoms of *Waldsterben* began around 1979–80 in many different parts of Europe and within four years the "disease" had spread over large areas of the continent.
2. As of late 1985, *Waldsterben* was still increasing in intensity and geographic distribution and is associated

Table 12.4 The 19 Major Forest Declines of the Last 50 Years

Pollution-Related Forest Declines

Widely assumed major role:

- *Waldsterben* in Europe
- Decline of ponderosa and Jeffrey pines in the San Bernardino Mountains, California
- Regional decline of white pine in the eastern United States and Canada

Possible major role:

- Decline of red spruce, and balsam, and Fraser firs at high elevations in the Appalachian Mountains from Georgia to New England
- Growth decline without other visible symptoms in loblolly, shortleaf, and slash pines in the Piedmont regions of Alabama, Georgia, North and South Carolina
- Growth decline without other visible symptoms in pitch and shortleaf pine in the Pine Barrens region of New Jersey
- Widespread dieback of sugar maples in northeastern United States and southeastern Canada

Declines Related to Biological or Physical Factors

- *Tannensterben* (white fir decline) in Europe
- *Kiefersterben* (Scotch pine decline) in East Germany and European Russia during early 1970s
- Oak decline in Germany and especially in France since early 1900s
- Decline of *Pinus pinaster* on the Atlantic coast of France since early 1980s
- Beech bark disease of northeastern United States and southeastern Canada
- Littleleaf disease of shortleaf pine in the southeastern United States
- Birch dieback in the northeastern United States and southeastern Canada
- Poleblight of western white pine in the Rocky Mountains
- Maple decline in the northeastern United States and southeastern Canada
- Oak decline in Pennsylvania, Virginia, and Texas
- Ash dieback in the northeastern United States and southeastern Canada
- Sweetgum blight in the southeastern United States

Note: A number of the declines attributed to biological or physical factors might involve toxic air pollutants, but studies are incomplete, and evidence insufficient to make a strong connection.

Source: Adapted from Cowling, 1985, Reference 20.

with an alarming frequency of damage from secondary stress factors such as insects, needle and root fungi, and climatic stresses (i.e., frost, wind, and snow damage).

3. Within five years it affected nearly every tree species in central Europe including the four most commercially important conifers (spruce, fir, pine, and larch) and six angiosperms (beech, birch, oak, ash, maple, and alder).
4. Various species of shrubs and herbs have been damaged in certain affected forests.
5. The symptoms are heterogeneous from one region to another, from one stand to another, and even within the same species in the same stand.
6. *Waldsterben* occurs with similar intensity on poor and rich soils, acid and basic soils, and on wet and dry soils, independent of their geological origin.
7. The symptoms often are more severe in higher elevations, but they occur in middle and low elevation sites as well.
8. Different forest management practices and the composition of the forest (i.e., single versus mixed stands, planted vs. natural) do not appear to have a significant impact on the amount of damage.
9. Young trees are normally not as severely affected as older ones, but even this varies from region to region.
10. Some of the typical symptoms have never been described before (especially for beech, spruce, and larch).
11. The worst damage appears in higher elevation forests on slopes facing the prevailing winds.
12. Most of the victims show both growth-decreasing and abnormal growth symptoms (23).

The *Waldsterben* phenomenon is characterized by three broad indicators of destruction: growth-decrease, abnormal growth, and water stress (24). (See Table 12.1.)

Dr. Cowling cautions that although the common symptoms of *Waldsterben* include increased susceptibility to biotic and abiotic stress factors, this dieback pattern is very different from the normal diseases induced by familiar biotic forest pathogens—fungi, bacteria, nematodes, insects, and viruses. "It is also distinct," says Cowling, "from the typical injuries to forests induced by drought and frost, or by gaseous air pollutants like ozone and sulfur dioxide" (25).

A widely accepted conceptual framework summarized recently by Dr. Paul Manion from the State University of New York helps to understand the complex interactions involved in forest declines. In this scheme, stress factors fall into three categories: predisposing, inciting, and contributing (26). Predisposing factors include climate, soil condition (moisture and nutrient supply), long-term atmospheric deposition of pollutants, and the genetic makeup and age of the tree. The effects of predisposing factors are generally asymptomatic. Inciting factors produce visible symptoms of injury. These include such abiotic stresses as drought and frost damage; biotic stresses like insect defoliation; and the short-term impacts from toxic gases (i.e., ozone, sulfur dioxide, etc.). These injure the tree and cause a relatively rapid deterioration of its condition. However, it is the contributing factors that actually "pull the trigger". Because of the interaction of the other two factors of decline, trees become susceptible to severe damage from abiotic stress agents like drought, frost, and wind damage as well as the usual litany of biotic stresses: insects, nematodes, fungi, mycoplasmas, bacteria, and viruses. Most of these agents may have been present always, but had little previous impact until the tree was weakened by predisposing and inciting factors (27). It is also interesting to note the overlapping role played by different stress agents. Drought, for example, can be a factor in all three categories.

Whether or not Manion's analytical framework can be applied entirely to *Waldsterben* remains to be seen. A number of scientists are convinced that airborne chemical fallout may play a role in all three decline categories—predisposing, inciting, and contributing.

The array of symptoms and the speed with which entire stands are affected suggests that the causes are multiple. *Waldsterben*, along with the North American decline, most certainly cannot be attributed to a single factor or even several factors. Emerging evidence points to the combined effects of a number of pollutants working synergistically, antagonistically, or in an additive manner. "Regional declines of forests on both continents are believed to result from the combined action of several different competitional, biological, physical, and chemical stress factors that act simultaneously or sequentially to induce the symptoms of damage," says Dr. Cowling (28).

The continuing debate swirling around the issue of acid deposition (commonly called acid rain) has, in a certain sense, only added to the muddle over the causes of *Waldsterben*. "When it comes to forest decline," declares Dr. Chris Bernabo, former Executive Director of the U.S. National Acid Precipitation Assessment Program, "the acidity of rainfall is no longer the primary issue. Many pollutants are probably involved in this process" (29).

Given this, the scientific community still continues to debate the role of air pollution and acid deposition in the European and North American forest decline syndromes. Is air pollution only a preconditioning factor? An inciting factor? A contributing factor? Or all three? Is it a primary agent? A secondary agent? Or both? And all this is further aggravated by the fact that so little is known about how forest trees respond to different kinds of stress factors.

Since the symptoms of *Waldsterben* in Europe and the regional declines of certain conifers in North America vary, the research efforts on opposite sides of the Atlantic also differ. Nevertheless, the two forest decline syndromes have a number of instructive, if not disconcerting, similarities. Recent research has revealed that the coniferous forests in both North America and Europe have been under continuous stress for the last three decades. Increment cores taken from thousands of conifers over the past few years show that their annual growth rings have become markedly narrower since 1970 as compared to the 1950s and 1960s. Growth declines of up to 20 percent have been observed in red spruce, and loblolly, shortleaf, and pitch pines in the eastern United States. In an interview with the *New York Times*, Dr. Samuel McLaughlin—

Photo R Bruck

This dead coniferous forest on Mount Mitchell, North Carolina, is the result of the complex interaction of multiple pollutants.

a forest physiologist working at the Oak Ridge National Laboratory in Tennessee—said that after examining core samples from 7,000 trees, representing 34 species in 15 states from Maine to Missouri, he had found "a systematic, regionally scaled and sustained decline in the growth of several species over the past 20–25 years" (30). In some severe cases, as on Mount Rogers in Virginia and on Mount Mitchell in North Carolina, the growth rates of red spruce and Fraser firs have been severely stunted. The radial growth of red spruce on Mount Mitchell and a few other sites has decreased an average of 82 percent, a fivefold drop since the 1960s (when compared to the period 1950–60) (31).

In Europe, diameter growth reductions began in white fir about 1960, followed by Norway spruce (circa 1970), and seem to have started in European beech as of 1978–80 (32).

These "invisible" growth symptoms, undetected until recently, occur long before the visible health of the tree begins to break down.

There are other connections too. In both Europe and North America the most severely damaged trees are those found consistently on higher elevation slopes facing the direction of the prevailing air masses, particularly those shrouded in clouds or fog much of the time (33).

Another disturbing aspect of *Waldsterben*—one more piece of circumstantial evidence pointing to air pollution stress—is the fact that mixed stands of trees are more damaged than monocultures. Air currents can penetrate the canopies of mixed forests more easily, while it takes longer for air masses to invade monocultures, where the trees are all roughly the same height (except at higher elevations and in steep terrain). Hungarian research has borne this out as well. Scientists there have even found that during heavy pollution episodes, peculiar kinds of circular air currents are created over mixed forests (34). But in the end, monocultures too succumb to the *Waldsterben* syndrome.

As the evidence mounts up, a growing number of U.S. scientists fear that the eastern forests of North America may soon experience *Waldsterben*-like symptoms over wide areas. "Something very dramatic is happening very quickly to the forests of the eastern United States, especially up the spine of the Appalachian Mountains," notes Dr. Robert Bruck, a plant pathologist at North Carolina State University in Raleigh and Project Leader of the Mount Mitchell study (35).

THE CHEMICAL ETIOLOGY OF *WALDSTERBEN*

Despite all the scientific squabbling over the causes of *Waldsterben* in Europe and the decline of coniferous forests in North America, there appear to be four broad areas of agreement at least among the scientists working on the air pollution connection. This emerging "consensus," tenuous as it is, involves the following assumptions:

1. Like cancer, *Waldsterben* must be understood as a disease syndrome, induced by multiple factors involving several "predisposing and stress-inducing factors, followed by numerous secondary effects of abiotic and biological origin" (36).
2. The primary causes are not due to insect or known forest pathogens, although these agents do play a secondary role.
3. Climatic factors such as drought or frost may also be involved, but their role is most probably secondary or "predisposing."
4. The atmospheric deposition of air pollutants or pollutant-related toxic, nutrient, or growth-altering substances are among the primary causes. The major air pollutants of concern are listed in Table 12.5.

Six "Schools of Thought" on Forest Decline and Air Pollution

Six major "schools of thought" or general concepts have evolved over the past five years to explain the role of air pollution in the forest declines observed in Europe (to a certain degree these also apply to North America). These hypotheses are: 1) General Stress; 2) Soil Acidification-Aluminum Toxicity; 3) Ozone and Sulfur Dioxide Injury; 4) Magnesium Deficiency; 5) Excess Nutrient or Excess Nitrogen; and 6) Growth-Altering Organic Chemicals (37).

1. General stress

This hypothesis was developed by a group of botanists, plant pathologists and physiologists at the University of Munich. According to Schütt, "air pollution and associated atmospheric deposition of nutrient, growth-altering or toxic substances has led, in recent years, to a decrease in net photosynthesis and associated diversion of photosynthate from mobile carbohydrates to less mobile and potentially toxic secondary metabolites" (38). In other words, this process leads to poorer energy status in the tree's root system, coupled to an increase in toxic substances in the shoots. This complex interaction eventually results in the "starvation" of the fine roots and mycorrhizae (fungus roots) as well as loss of needles or leaves. Since the tree's overall energy balance is reduced, it is much more susceptible to other stress agents like drought, frost, and wind, as well as any number of secondary biotic pathogens (39) (just as a starving person of-

Table 12.5 Chemical and Physical Nature of the Most Common Air Pollutants

- Sulfur dioxide (SO_2): A colorless gas produced during combustion of sulfur-containing fossil fuels (i.e., coal and oil) and during smelting of sulfide metal ores. SO_2 is emitted mainly by large stationary sources such as fossil fuel-fired power plants, metal smelters, and other industrial and commercial installations.
- Nitrogen oxides (NO_x): Two colorless gases (NO and NO_2) produced in any high temperature processes (i.e., combustion of coal, oil, gasoline, and natural gas). NO_x are emitted by both stationary sources and transportation vehicles.
- Toxic metals: Lead, cadmium, nickel, and other toxic elements (e.g. fluorine) released mainly by large metal smelters and by transportation vehicles using leaded gasoline.
- Volatile organic compounds (VOCs): A wide variety of carbon compounds ranging from such simple molecules as ethylene, gasoline, and cleaning and painting solvents, to complex compounds such as pesticides. VOCs are produced by many different, usually small, stationary, and mobile sources.
- Carbon monoxide (CO): A colorless and odorless but highly toxic gas produced during incomplete combustion of coal, oil, gas, or incineration of garbage and other waste products. Carbon monoxide inhibits respiration in humans and other animals. It is of concern to society mostly in urban areas where it accumulates in stagnant air mainly from transportation vehicles.
- Particulate matter: A catch-all category of pollutants. The substances of concern range from coarse "fugitive dust" particles that cause soiling of textiles, windows, paints, etc., to fine aerosol particles that cause atmospheric haze or are drawn into the lungs where they induce respiratory disease.

  These substances are very diverse, both chemically and physically. The larger particles range from almost pure carbon in the case of soot from oil burners, to mineral dusts in the case of manufacturing facilities that produce cement, asbestos, clay, ceramics, textiles, and other materials. The fine particles range from smoke to all sorts of sulfate ammonium, organic, metallic, and other fine aerosol particles formed by condensation of gaseous and other volatile atmospheric substances. Some of these particles have remarkable and complex fine structures that are characteristic of the original sources of emissions.
- Ozone (O_3) and other photochemical oxidants: These substances occur only as secondary pollutants. They are produced when NO_x and VOCs interact with atmospheric oxygen in the presence of sunlight. Ozone is the most important photochemical oxidant. It is one of the most toxic gases to which plants and human beings are exposed in the environment.
- Acid deposition: Acidic and acidifying substances produced when SO_2, NO_x, and HCl combine with oxygen and moisture in the air to give aqueous solutions or aerosols of sulfuric, nitric, and hydrochloric acids. Acid deposition occurs when these substances are dissolved in rain, snow, hail, dew, and fog (wet deposition). It also occurs by dry depositions of sulfate, nitrate and chloride aerosol particles, and as gaseous SO_2, NO_x, HNO_3, and HCl. The acidic substances in wet and dry deposition may be partially or completely neutralized by alkaline soil elements such as calcium, magnesium, potassium, and sodium, or by ammonium ions. Acidification of aquatic and terrestrial ecosystems also occurs when ammonium sulfate aerosol and other ammonia or ammonium compounds are taken up by plants after deposition into ecosystems.

Source: Cowling, 1984, Reference 121

ten succumbs to some common disease or infection before dying from lack of food).

2. Soil acidification—aluminum toxicity

This hypothesis was advanced by Dr. Bernhard Ulrich and his colleagues at the University of Göttingen, West Germany. The concept rests on Ulrich's long-term studies of nutrient cycling carried out on the Solling Plateau near Göttingen. According to Ulrich, the natural acidification of forest soils (due to a number of processes, including humus disintegration and nitrification) is accelerated by the chronic atmospheric deposition of wet or dry acidic, or acidifying substances (40). Acids drastically alter the chemical structure of soils and plants. In ecosystems subjected to a constant "acid bath," nutrients like calcium, magnesium, and potassium that are essential for growth are eventually leached from the soil by acidified particles, while aluminum (present in all soil) is liberated and becomes toxic. Just as the process of aluminum toxicity, generated by acid rain, kills freshwater fish and other aquatic life, mobilized aluminum in the soil attacks the fine roots of the trees, resulting in necrosis. This, then, leads to increased moisture and/or nutrient stress and eventually to "drying out" and death of the trees, particularly during drought periods (41). Because their root systems are so damaged, the afflicted trees cannot take up needed nutrients from the soil nor enough water to survive. Using this data, Dr. Ulrich predicted the decline of Europe's forests in 1979.

3. Gaseous pollutant injury—ozone and sulfur dioxide

This hypothesis has been advocated particularly by Dr. B. Prinz of the Landesanstalt fur Immissionsschutz in Essen, West Germany. It is founded on many field observations and measurements of ozone and sulfur dioxide concentrations in West Germany as well as on controlled exposures of seedlings to these pollutants alone and in various combinations (42). So far, only the yellowing or browning of needles and leaves have been duplicated in laboratory studies.

Despite the fact that ozone levels are known to be high in many parts of Europe, data on its actual extent and effects are "patchy." In North America, ozone has been identified as a primary factor in the decline of pine forests for the past 20 years.

4. Magnesium deficiency

This hypothesis has been advanced especially by Professor Karl Rehfuess of the Department of Soil Sciences at the University of Munich. It is founded on field observations and both foliar and chemical analyses in spruce stands at high elevations (43). Rehfuess believes that the yellowing of spruce foliage is due to extreme magnesium deficiency, and concludes that "acid deposition . . . may contribute to these growth disturbances; it adds nitrogen to the ecosystem but may leach out magnesium and calcium from needles and soils. The leaching from foliage is presumably accelerated by episodic ozone or frost damage to cuticles and cell membranes" (44).

5. Excess nutrient or excess nitrogen

This hypothesis is the result of cumulative research over the past 20 years and is based on the premise that with the onset of the Industrial Revolution—and the "mass production" of man-made sources of pollution—forest ecosystems have been receiving excessive doses of the 16 elements considered essential for all plant growth (45). All 16 elements can be taken up by trees through their foliage or roots.

In particular, the atmospheric deposition of nitrogen over wide areas has increased dramatically since the Second World War and could be contributing to the *Waldsterben* syndrome in Europe as well as the forest declines in North America. "Excess nitrogen is known to induce the following detrimental effects," write Schütt and Cowling, "increased growth and hence increased demand for all other essential nutrients may lead to deficiencies of these other elements; inhibition or necrosis of mycorrhizae; increased susceptibility to frost; increased susceptibility to root-disease fungi; changes in root-shoot ratios; and altered patterns of nitrification, denitrification, and possibly nitrogen fixation" (46). In other words, just as crops can be overfertilized and "burn up," so forests can fall victim to "overfertilization" by excessive airborne deposition of nutrients.

6. Growth-altering organic chemicals

This very speculative hypothesis was suggested by Professor Fritz Führ, Director of the Institute of Radioagronomy at Jülich, near Bonn, West Germany. Führ postulates that among the thousands of organic compounds produced every year in Europe and North America, a few of them—singly or in combination—may produce some of the growth-altering symptoms described earlier (47). (See Table 12.1.) Ethylene and aniline are examples of such compounds.

Air Pollution Damage Mechanisms

Since there is no single hypothesis that can explain all the symptoms of damage observed, ten specific damage mechanisms based on these six "schools of thought" have been postulated to explain the means by which airborne chemicals may contribute to forest declines. (See Table 12.6.) As mentioned before, Table 12.2 compares the symptoms of the forest declines in North America and Europe and links them with possible etiological agents.

Ozone Damage

Ozone (O_3) and other photochemical oxidants—including PAN (peroxacetyl nitrate), PPN (peroxyproprionyl nitrate), and hydrogen peroxide—have been known to damage trees and other vegetation in concentrations of as little as 100–200 micrograms per cubic meter ($\mu g/m^3$) for periods of six hours or more extending over several days (48). Ozone damage to crops in the United States has been estimated to cost roughly $1–2 billion a year (49). So far, no monetary figure has been placed on ozone damage to forests, but the eventual price tag could be staggering.

Ozone is formed when nitrogen oxides and volatile hydrocarbons (also known as volatile organic carbon—VOC) react with oxygen in the presence of sunlight, particulary when UV radiation is high. The major sources of these precursor chemicals are fossil-fuel-fired power stations, industrial processes, refineries, vehicle exhausts, and volatilization of organic solvents and fuels. Once in the atmosphere, this chemical "soup" becomes highly reactive.

In central Europe ambient ozone levels vary from 50 to 250 $\mu g/m^3$, and in West Germany hourly mean concentrations ranging from 100 to 250 $\mu g/m^3$ are quite common over wide areas, with peak values reaching 400 $\mu g/m^3$ (50). Over the past 20 years, there has been a clear upward trend in ozone concentrations in both East and West Germany (51). Furthermore, nitrogen oxide emissions—important in the formation of ozone—have increased by 50 percent between 1966 and 1978 in West Germany (52). Similar ozone levels are found throughout the United States.

Figures 12.2 and 12.3 show the major pathways by which ozone may damage trees. The most extensive work on ozone pollution in relation to forest decline has been done in the United States. European research into ozone damage is fragmentary and has usually been done in connection with sulfur dioxide fumigation studies.

Two large-scale studies carried out in the United States are particularly relevant to hypothesis 1 (Figure 12.2), which maintains that ozone directly damages foliar tissues. Both studies conclusively link ozone pollution to forest damage (53). The first—carried out in the San Bernardino Mountains, east of Los Angeles, California—

Table 12.6 Ten Hypotheses on How Air Pollution Could Cause Forest Decline

Hypotheses Involving Direct Effects:

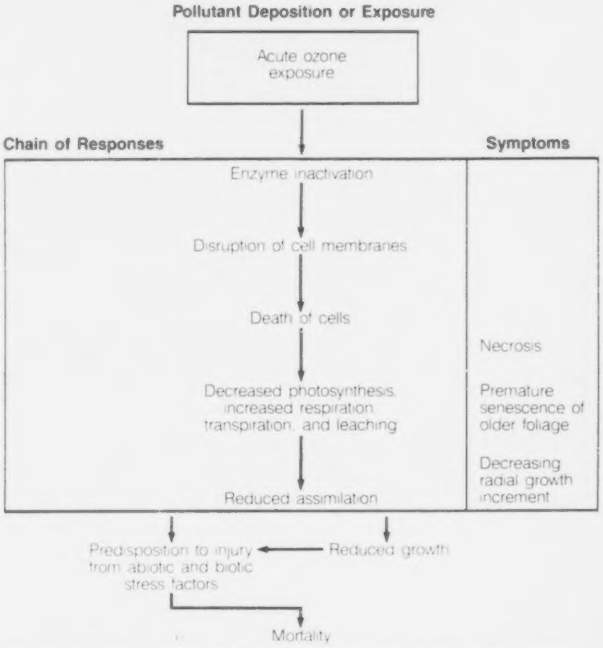
1. Ozone damage and decreased photosynthesis efficiency
2. Ozone damage in combination with acid rain and increased foliar leaching
3. Sulfur dioxide damage
4. Foliar fertilization and increased winter injury (excess nitrogen deposition)
5. Foliar fertilization and altered nutrient allocation (excess nitrogen deposition)
6. Growth-altering organic substances
7. Nutrient leaching from foliage (acid deposition)

Hypotheses Involving Indirect Effects:

8. Nutrient leaching from soil (acid deposition)
9. Aluminum mobility and toxicity (acid deposition)
10. Heavy metal toxicity (heavy metal deposition)

Source: A. Bartuska *et al.*, 1985, Reference 21.

Figure 12.2 Hypothesized Pathway Involving Direct Ozone Damage to Foliar Tissue


Pollutant Deposition or Exposure
Acute ozone exposure
Chain of Responses
Symptoms
Enzyme inactivation
Disruption of cell membranes
Death of cells
Necrosis
Decreased photosynthesis, increased respiration, transpiration, and leaching
Premature senescence of older foliage
Decreasing radial growth increment
Reduced assimilation
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 1.

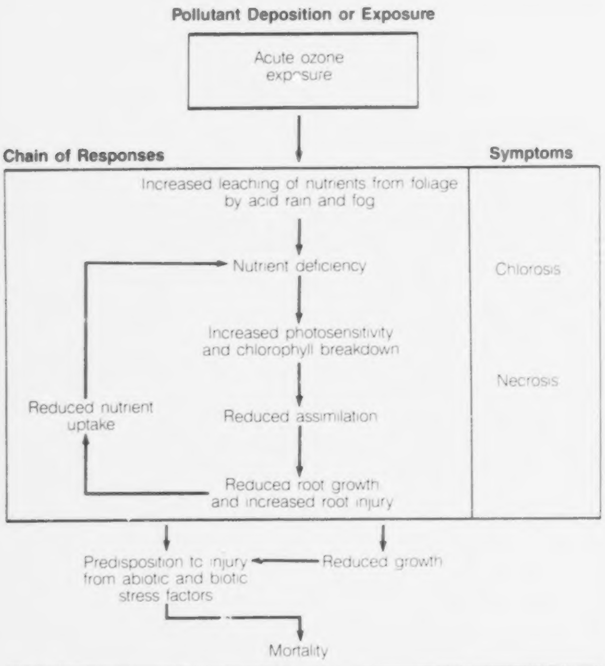
Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

concentrated on ponderosa and Jeffrey pines, American white fir (*Abies concolor*), black oak, and incense cedar, while the second focused on eastern white pine (*Pinus strobus*) in Virginia. The results demonstrated that "ozone induced foliar injury and premature leaf fall, leading to decreased photosynthetic capacity, decreased radial (annual) growth, and reduced nutrient retention in foliage. This weakening of the trees led to increased susceptibility to pine beetles and root rot, thus leading to mortality" (54).

It was stressed, especially in the San Bernardino study, that ozone predisposes the trees to insects, pathogenic fungi, and other biotic agents which finish them off; ozone does not, in itself, kill the trees.

The second hypothesis involving ozone (Figure 12.3, hypothesis 2) suggests that ozone exposure in combination with acid mist or fog increases nutrient leaching from the leaves or needles, and the resulting nutrient deficiencies (e.g., magnesium and calcium) reduce photosynthesis and biomass production both in the canopy and in the root systems (55). This loss of magnesium may account for the yellowing of spruce needles commonly seen in West Germany, since magnesium plays a central part in the structure of the chlorophyll molecule, as iron does in hemoglobin. The loss of magnesium and calcium from the leaves causes the roots to work overtime to replace these crucial nutrients, and the resulting transfer of these nutrients from the soil increases the hydrogen-calcium ratio in the soil, and hence the acidity. The major evidence comes from studies coordinated by Dr. Prinz and colleagues in the North-Rhine Westphalia region of West Germany. Field observations and analysis showed that all age classes of Norway spruce and white fir are affected, but lab experiments could duplicate only the characteristic mottling and chlorosis of needles in spruce, not white fir (56). Although it is known that ozone together with acid rain is a nasty combination, so far field observations have not been successfully duplicated under controlled conditions.

Figure 12.3 Hypothesized Pathway Involving Ozone Damage and Accelerated Foliar Leaching


Pollutant Deposition or Exposure
Acute ozone exposure
Chain of Responses
Symptoms
Increased leaching of nutrients from foliage by acid rain and fog
Nutrient deficiency
Chlorosis
Increased photosensitivity and chlorophyll breakdown
Necrosis
Reduced nutrient uptake
Reduced assimilation
Reduced root growth and increased root injury
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 2.

Source: Adapted from A.M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

Ozone in combination with acid deposition (and heavy metals) may also be playing a major role in the deterioration of Hungary's forests. Dr. R. Solymos, head of the Forestry Department in the Ministry of Agriculture, states that the serious oak decline observed in Hungary is due to this combination, which "fosters the aridity noticed in the oaks, causing trees to die from the top down, with yellowing of the leaves and complete shedding of bark. This, in turn, leads to the appearance of fungal pathogens and insects which dispatch the trees in short order" (57).

Sulfur dioxide damage

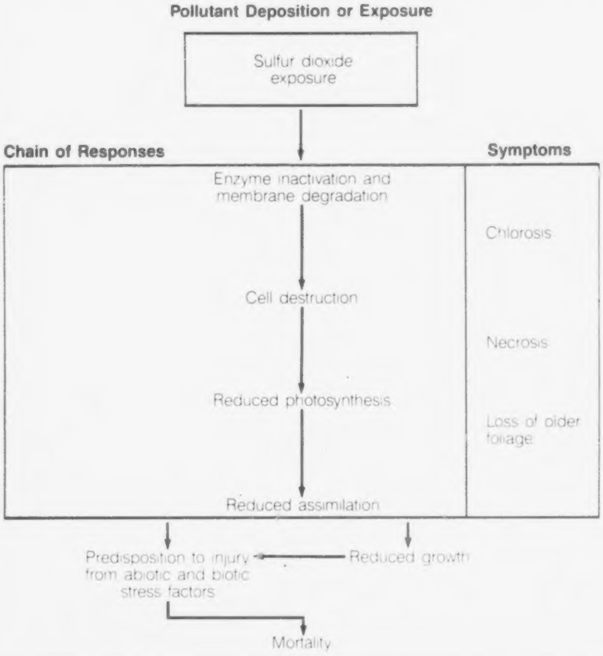
Gaseous sulfur dioxide (SO_2), a product mainly of the combustion of fossil fuels in power plants and industrial processes, is a potent pollutant even before mixing in the atmosphere with nitrogen oxides to form acid rain. Somewhere between 110 and 115 million metric tons of SO_2 are emitted across Europe (including Eastern Europe and the USSR) and North America every year (58). Despite this tremendous amount of pollution, acute SO_2 damage to forests is limited to areas surrounding major point sources. Nevertheless, a vast literature has grown up around SO_2 injury to trees and vegetation in the vicinity of power plants, metal smelters, and other polluting industries.

It has been well established that SO_2 injures trees by entering the stomata (pores) in the leaves or needles, where it reacts with water to form sulfuric acid, which collects in a thin film on the cell walls. The results are easy to spot: the leaves on deciduous trees take on a "bleached" look, while the needles on conifers turn red-brown.

Figure 12.4 (hypothesis 3) details the pathway by which acute exposure to SO_2 causes alterations in enzyme activity and cell destruction within leaf and needle tissues, resulting in physiological changes and reduced growth (59).

SO_2 pollution has also been linked to overall reduction in radial growth and, in some severe cases, death of nearly all vegetation near heavily polluting industries. The classic example of point source SO_2 pollution is the Inco metal smelter in Sudbury, Ontario (Canada)—the largest single source of sulfur dioxide pollution in the world (650,000 tons per year, more than Sweden's total output). Complete mortality of vegetation was reported in an inner zone of 1,865 square kilometers surrounding the smelter (60). Similar "tree graveyards" have been observed

Figure 12.4 Hypothesized Pathway Involving Sulfur Dioxide Damage to Foliar Tissue



Note: See Table 12.6, Hypothesis 3

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

in southern East Germany and northwestern Czechoslovakia, where SO_2 and "smoke" damage is extensive (61).

However, the typical symptoms associated with SO_2 damage have not been found in West German forests, except where connected to an identifiable point source. Average annual SO_2 concentrations in pollution-damaged West German forests range from 7 to 21 grams per cubic meter (g/m^3), well below the permanent damage level which begins at almost 40 g/m^3 (62). Given this fact, Professor Rehfuess has advanced the notion that SO_2 damage in Central Europe may be due to chronic stress brought on by low level doses over a long period (63). It should be noted, however, that peak half-hour mean concentrations can reach 1,000 $\mu g/m^3$ or more, even in "clean air" regions in Central Europe (64).

Excess nitrogen-nitrate-ammonia deposition

Of the 16 elements considered essential to forest growth, nitrogen is generally regarded as the most critical nutrient regulating optimal forest productivity. Experimental evidence suggests that if more nitrogen than usual is available, the tree takes up the added nitrogen, thereby increasing its need, proportionally, for other important nutrients. If they are not available, then the tree's normal physiology is disrupted (65).

The main anthropogenic source of nitrogen is agricultural fertilizers, but it also originates from sewage sludge treatment, from chemical fertilizer plants, and (a very small amount) from vehicle exhausts. In Europe about 70 percent comes from agricultural land (and sewage treatment) and 10–20 percent from natural sources (66).

Fertilizer use is massive throughout the developed world. In Sweden, for example, the average application of nitrogen-based fertilizers is 80 kg per hectare per year. North American studies have found that 10 percent of all applied doses of nitrogen fertilizers evaporate into the atmosphere. In Sweden, it has been estimated that every year some 25,000 metric tons of nitrogen go up, while over 80,000 metric tons come down as wet deposition alone, pointing to substantial transboundary transport (67). Futhermore, across wide areas of Central Europe and the midwestern United States, 10–25 kg/ha/year of nitrogen falls in wet plus dry deposition (in West Germany the range is 15–30 kg/ha/year) (68). By contrast, in "clean" unpolluted areas deposition is less than 1 kg/ha/year (69).

However, in the higher elevation spruce-fir forests of the northeastern United States, total atmospheric nitrogen is estimated to be as high as 37–44 kg/ha/year, with at least half of it coming down as wet deposition (70).

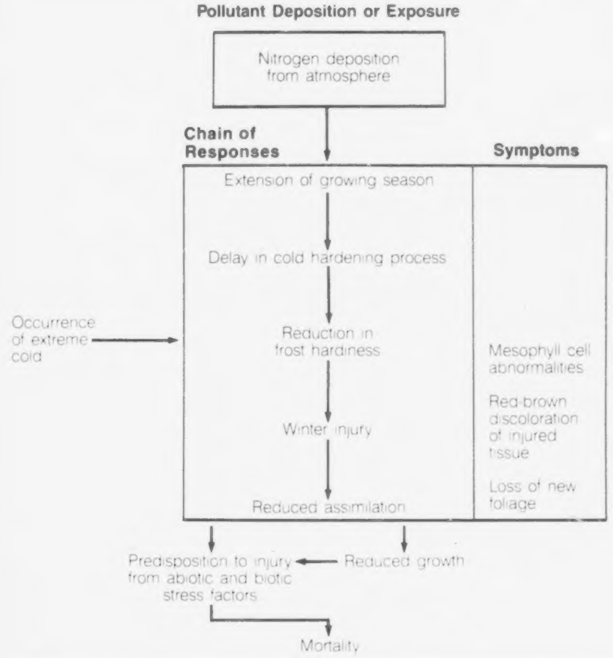
There are two hypotheses as to how excess nitrogen-ammonia deposition harms forests (Table 12.6): through increased fertilization of foliage, leading to more winter damage (Figure 12.5) and through excessive fertilization of foliage in combination with altered nutrient allocation within the trees' metabolic system (71). (See Figure 12.6.)

The mechanism of destruction illustrated in Figure 12.5 is straightforward: in a sense, excess nitrogen stimulates the tree into extra growth activity, thereby prolonging the growing period, so that the trees do not have enough time to prepare for winter (72). Normally, trees and shrubs must go through a cold-hardening process in autumn, when they essentially stop growing and undergo important metabolic changes (somewhat akin to hibernating animals). Too much nitrogen at this critical stage, and the adjustment process is totally disrupted.

The visual symptoms of damage include red-brown discoloration of the needles and needle loss in spring. These symptoms have been observed in Central Europe and in higher elevation sites in the United States from North Carolina to Vermont.

The second nitrogen hypothesis (Figure 12.6) links excess nitrogen deposition to changes in the allocation patterns of carbon and other nutrients within the plant, predisposing the tree to lethal secondary pathogens like nematodes, fungi, and insects (73). Because increased nitrogen overstimulates the tree, causing it to take up greater quantities of other nutrients, the tree soon depletes its soil mineral reserves. In order to compensate for this, the tree's overall root mat system eventually shrinks, making it susceptible to drought in summer and wind-throw in winter. Overfertilization of nitrogen by even 10 percent above normal levels is enough to affect the feeder root systems (ectomycorrhizae) of some trees, as well as rendering the trees more palatable for insects (74).

Figure 12.5 **Hypothesized Pathway Involving Foliar Fertilization by Nitrogen and Reduction in Frost Hardiness**


Pollutant Deposition or Exposure
Nitrogen deposition from atmosphere
Chain of Responses
Symptoms
Extension of growing season
Delay in cold hardening process
Occurrence of extreme cold
Reduction in frost hardiness
Winter injury
Reduced assimilation
Mesophyll cell abnormalities
Red-brown discoloration of injured tissue
Loss of new foliage
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 4

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

Citing Swedish research, Bengt Nihlgård, a plant ecologist at the University of Lund, has surmized that "nitrogen-saturated forests would begin to appear after 20–25 years if the nitrogen deposition rate was in the range of 30 kg/ha/year" (75). Much of Europe and some high elevation sites in North America are already approaching such levels.

Growth-altering organic substances

Professor Fritz Führ at Jülich has added this ingredient to the *Waldsterben* stew. "No one knows about the role of organic chemicals in forest death and this is a critical area," insists Führ. "Today, some 1.5 million tons of organic chemicals—pesticides, herbicides, and thousands of others—are released across the Federal Republic every year. Some of these may interfere with the tree's hormone production system and other processes" (76). Dr. Peter Schütt agrees: "in one study we found traces of 400 organic compounds in one cubic meter of ambient air" (77).

Hypothesis 6 (Figure 12.7) may be rather speculative, but there is at least one instance linking the atmospheric deposition of synthetic organic compounds to the abnormal growth symptoms seen in West Germany (and on Mount Mitchell, North Carolina). The chemical, aniline, has been implicated in the rapid mortality of loblolly pines near a chemical plant not far from Raleigh, North Carolina. Major symptoms include browning of needles, shedding of needles while still green, and death of mature trees (78).

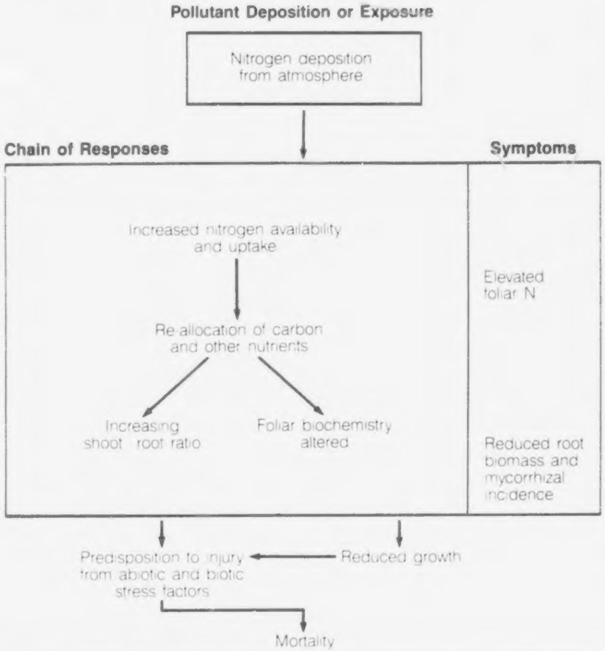
Ethylene is also known to affect plant growth, causing leaf abscission (shedding of leaves and needles) in concentrations as low as 0.1 gram per liter of air (79).

Auxin, an important plant hormone, has also been linked to leaf curling and distortion of leaf blades or needles; in higher concentrations it is used as a herbicide. Professor Schütt speculates that two chemicals may come together in a binary fashion (80)—like chemical warfare agents—forming a highly toxic substance in very small quantities. This hypothesis needs the most attention, as little has been done, to date, to show how organic chemicals (particularly those used in the manufacture of herbicides and pesticides)—singly or combined—may play a role in forest decline and death.

Acid deposition

Acid deposition is a combination of sulfur dioxide and nitrogen oxides together with hydrogen chloride and

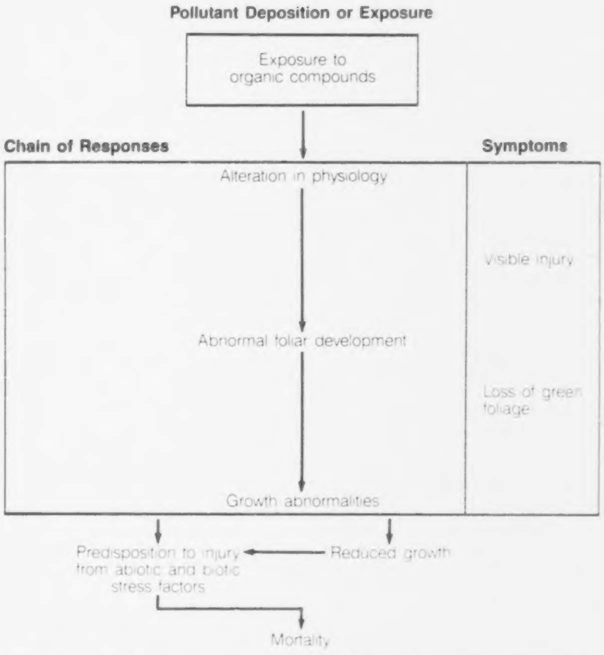
Figure 12.6 **Hypothesized Pathway Involving Changes in Nutrient Allocation Patterns as a Response to Increased Nitrogen Availability**


Pollutant Deposition or Exposure
Nitrogen deposition from atmosphere
Chain of Responses
Symptoms
Increased nitrogen availability and uptake
Elevated foliar N
Re-allocation of carbon and other nutrients
Increasing shoot : root ratio
Foliar biochemistry altered
Reduced root biomass and mycorrhizal incidence
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 5

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

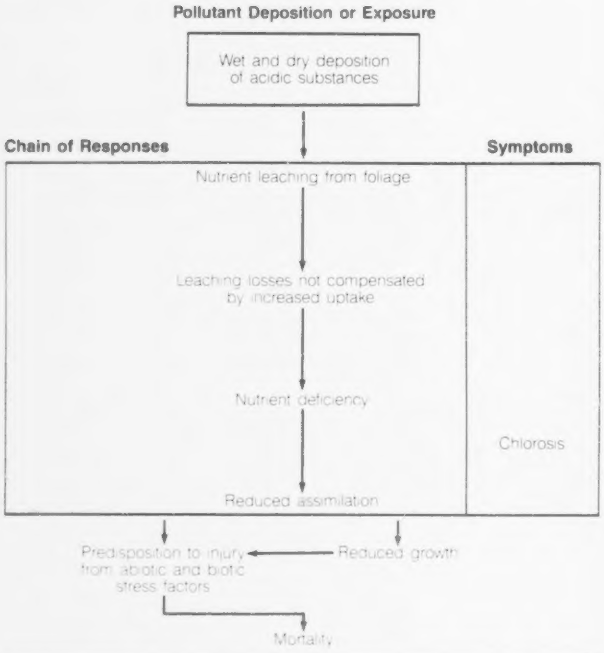
Figure 12.7 Hypothesized Pathway Involving Growth Altering Substances and Altered Physiology


Pollutant Deposition or Exposure
Exposure to organic compounds
Chain of Responses
Symptoms
Alteration in physiology
Visible injury
Abnormal foliar development
Loss of green foliage
Growth abnormalities
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 6.

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

Figure 12.8 Hypothesized Pathway Involving Foliar Leaching and Nutrient Imbalance


Pollutant Deposition or Exposure
Wet and dry deposition of acidic substances
Chain of Responses
Symptoms
Nutrient leaching from foliage
Leaching losses not compensated by increased uptake
Nutrient deficiency
Chlorosis
Reduced assimilation
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 7.

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

other compounds which mix in the atmosphere with oxygen and water vapor to form dilute solutions of strong mineral acids. These substances then fall to earth as acid rain, snow, or fog, or as acidified dry particles. Acid deposition originates mainly from fossil-fuel-fired power stations and industrial processes, although NO_x comes about equally from vehicle exhausts. (See Table 12.5.)

Foliar leaching is considered a normal part of the tree's nutrient cycling system and does not inherently pose any threats to health. However, the tree's critical internal clock, or nutrient balance, must be maintained. A number of studies in North America have shown that acid precipitation in the range of pH 2.3–5.0 leached potassium, calcium, and magnesium from the leaves and needles of sugar maples, yellow birch, and white spruce (81). Despite the fact that many forest ecosystems in Europe and North America regularly receive up to 30 times more acidity than is deposited in unpolluted, "pristine" environments, so far there is no evidence that foliar leaching affects overall productivity and growth.

Figure 12.8 (hypothesis 7) shows the pathway by which essential plant nutrients, particularly base cations, are removed from leaves and needles at an accelerated rate due to acid deposition. (See Table 12.6.) Ozone's role in leaching nutrients from foliage has already been discussed.

Research on 194 forest sites in southwestern West Germany demonstrated that trees attempt to compensate for foliar leaching by taking up more nutrients from the soil (82). If nutrients are not available, the trees are more susceptible to climatic stresses.

Dr. Bernhard Ulrich, the main proponent of hypotheses 8 and 9, contends that acid deposition accelerates normal soil acidification processes. Ulrich's work on the Solling Plateau has demonstrated that acid deposition does leach essential nutrients from the soil, at the same time mobilizing aluminum, which then damages the root systems (83).

Figure 12.9 (hypothesis 8) shows the pathway through which plant nutrients are leached from the root zone of the soil by acid deposition. As discussed previously, soil acidification is a natural process that takes place in most soils in humid climates.

However, this entire process is very site specific. Soils with high buffering capacities—like much of the U.S. Midwest, which sits atop limestone or sandstone formations—are not as affected by acid deposition as are those soils found above thin glacial tills or thick granitic bedrock (as in much of Scandinavia, Canada, and parts of

Central Europe). In other words, thin soils with restricted root zones are more vulnerable to the effects of acid leaching than richer, deeper soils with higher concentrations of buffering agents like calcium and potassium. Another factor to consider is that each tree is different. Individual trees, like people, react differently to environmental stresses.

The third part of this acid rain "trilogy" (Figure 12.10) shows how acid deposition may mobilize phytotoxic concentrations of aluminum in the soil, which then kills the fine feeder roots. During spring snow melts, soils also experience acid "pulses" in which great quantities of aluminum and other heavy metals are liberated at the same time, soaking into soils and leaching into water courses. Dr. Ulrich found that aluminum concentrations of as little as 1–2 milligrams per liter (mg/l) in soil solutions could damage root systems (84). At Solling, he found 6 mg of aluminum per liter under beech forests and 15 mg of aluminum per liter under spruce forests, well above his threshold levels for injury (85).

On the other hand, Norwegian research carried out by Abrahamsen and Tveite suggests that concentrations of aluminum must be 80–160 mg/l in solution before damage to roots is evident (86). The wide differences in findings have been swept aside as "site specific." Says Ulrich, "soils with reserves of calcium are not as affected by mobilized aluminum as soils with less buffers" (87).

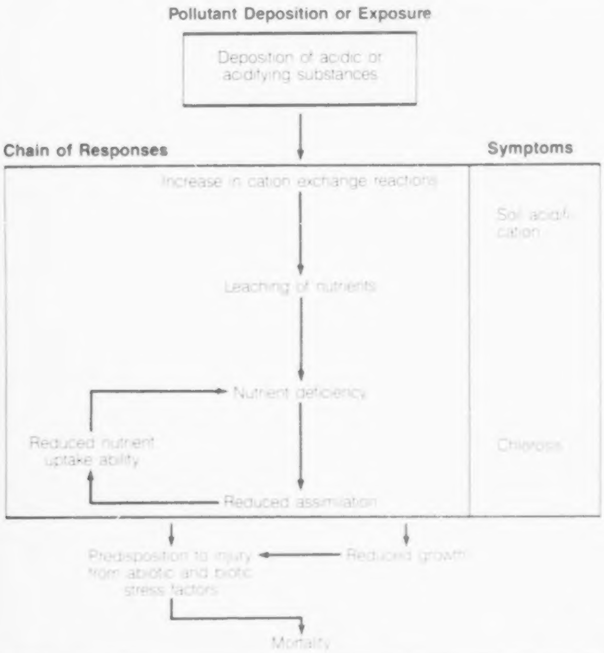
Soil acidification and aluminum toxicity appear to be problems in some parts of Europe, where middle- to higher-elevation spruce-fir forests are found on mineral soils, with poor buffering capacities. By contrast, the higher elevation forests in the eastern United States are mostly found on organic soils. For this reason, U.S. scientists place acid rain much farther down the list of possible causes of forest decline than is the case in Europe.

Heavy metal deposition

Heavy metals in the atmosphere result from the combustion of fossil fuels in power plants and industry and from the smelting of metal ores, although leaded petrol (gasoline) is also a major source of airborne lead.

Elevated levels of lead, cadmium, copper, and zinc, in particular, have been found in forest litter and soils at higher elevations throughout the Appalachian chain up to New England. As much as 2 grams of total lead per square meter of forest floor (up to ten times normal concentrations) have been found at Camel's Hump, Vermont, and at Mount Mitchell, North Carolina (88).

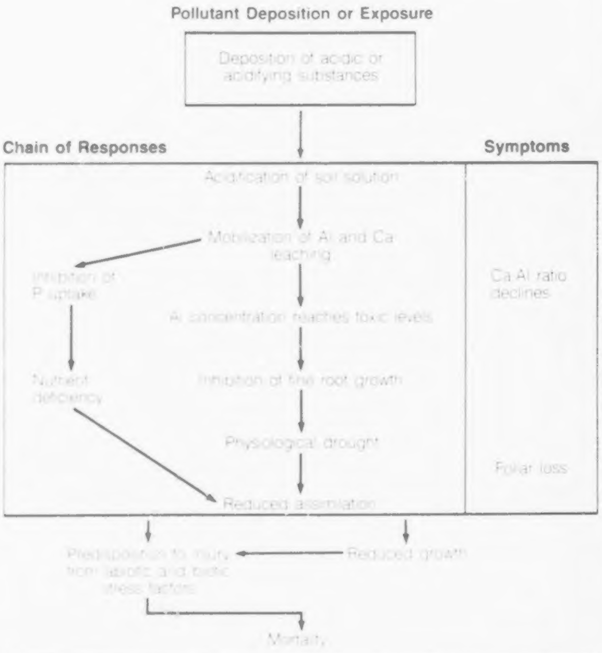
Figure 12.9 Hypothesized Pathway Involving the Development of Nutrient Deficiencies in Trees Due to Excessive Cation Leaching from Soils


Pollutant Deposition or Exposure
Deposition of acidic or acidifying substances
Chain of Responses
Symptoms
Increase in cation exchange reactions
Soil acidification
Leaching of nutrients
Nutrient deficiency
Reduced nutrient uptake ability
Chlorosis
Reduced assimilation
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 8.

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

Figure 12.10 Hypothesized Pathway Involving Aluminum Toxicity and Forest Species Response


Pollutant Deposition or Exposure
Deposition of acidic or acidifying substances
Chain of Responses
Symptoms
Acidification of soil solution
Mobilization of Al and Ca leaching
Inhibition of P uptake
Ca:Al ratio declines
Al concentration reaches toxic levels
Nutrient deficiency
Inhibition of fine root growth
Physiological drought
Foliar loss
Reduced assimilation
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 9.

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

Andrew Friedland, from the University of Pennsylvania, discovered 200 mg of lead per gram of soil in the forest litter on Camel's Hump, where 70 percent of the red spruce on the west slopes shows serious damage (89). Comments Friedland, "lead is raining down here at the rate of 700 grams per hectare, but it is not being taken up by the trees; most of it remains in the soil where it interferes with microbial processes" (90).

U.S. Environmental Protection Agency studies indicate that lead can inhibit root growth and root elongation at levels between 3 and 10 grams per gram of soil (91). But the worst effects from toxic metals may be more indirect and much more insidious over the long term.

Dr. D.R. Jackson and coworkers found that heavy metals are indeed mobile (particularly when combined with acid rain) and contribute to increased nutrient leaching. However, Jackson concluded, "soil nutrient cycling processes are more sensitive to heavy metal contamination than plant assimilation processes" (92). Apparently, beneficial soil microorganisms, especially fungi and bacteria, are inhibited by heavy metals and fail to break down organic matter into the nutrients trees need, thus altering normal biogeochemical cycling patterns.

It is also known that soil acidity has a profound effect on the mobilization and utilization of lead, as well as other heavy metals. In controlled studies, soil microorganisms exhibited marked metal toxicity as the soil pH was lowered (93).

Hypothesis 10 holds that atmospheric deposition of heavy metals interferes with normal plant functions. Figure 12.11 shows the pathway whereby heavy metals may interfere with both plant and soil microbial processes.

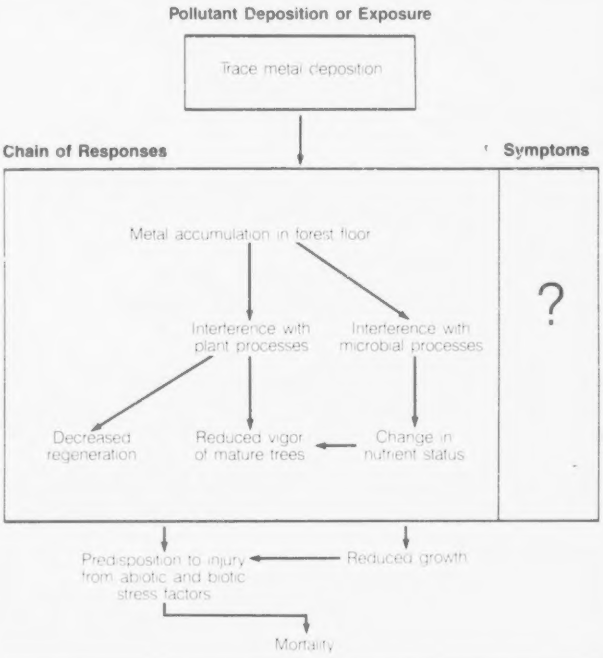
So far, West German research has not been able to find phytotoxic quantities of lead or other heavy metals in soils of *Waldsterben*-affected forests. But this does not mean that heavy metals do not play a role. The North American work on heavy metal contamination of forests is much more thorough than European efforts. Heavy metals may be working together with other pollutants to create multiple simultaneous stresses to forest ecosystems at specific sites over wide areas.

Ranking the Suspects

As the research programs in Europe and North America begin to narrow down the field of suspects, it is apparant that the agents of destruction vary from region to region and even from stand to stand in the same area. Since there are important regional and even local differences in the symptoms of *Waldsterben*, the mix of causal factors gets shuffled around from one place to another. In this decline syndrome, nothing remains constant. Researchers find the clues shifting from under them as they try to compare the data from different sites.

Nevertheless, a scientific consensus is emerging as to the primary etiological agents. (See Table 12.7.) Since biotic and abiotic factors are considered, by and large, to play secondary roles, only pollutants are included on the lists. As is evident, the North American picture differs from the forest decline in Eastern and Western Europe. The same major pollutants are thought to be at work, but in different orders of magnitude and importance.

Figure 12.11 Hypothesized Pathway Involving Heavy Metal Toxicity


Pollutant Deposition or Exposure
Trace metal deposition
Chain of Responses
Symptoms
Metal accumulation in forest floor
Interference with plant processes
Interference with microbial processes
?
Decreased regeneration
Reduced vigor of mature trees
Change in nutrient status
Predisposition to injury from abiotic and biotic stress factors
Reduced growth
Mortality

Note: See Table 12.6, Hypothesis 10.

Source: Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

THE BURDEN OF RESEARCH

The West German research programs are the most extensive and heavily funded in Europe. Official estimates put the total research effort in the Federal Republic at roughly 300 projects on both federal and state levels, soaking up about DM 205 million (deutsche marks) a year (US $68 million) (94).

The Federal Ministry for Research and Technology (the main coordinating ministry), in an effort to correct the helter-skelter approach to forest decline research, has designated two centers as focal points for its official work on the biological effects of *Waldsterben*. Both centers—KFA at Jülich, outside Bonn, and GSF at Munich—although primarily nuclear research establishments, have departments or institutes that have been active in environmental research for some years. In 1985, Jülich administered DM 29 million of the Ministry's research funds and supervised 64 research groups (95). GSF in Munich works with 11 other institutes and is the headquarters for a series of elaborate chamber studies, where seedlings are being subjected to a variety of airborne chemicals, singularly and in combination, under varying climatic conditions, in an effort to see if any more of the classic *Waldsterben* symptoms can be duplicated in the laboratory (96). Despite the obvious limitations of such studies (it is difficult to duplicate nature in a test tube), if more symp-

Table 12.7 Airborne Pollutants that May Play Significant Roles in the Forest Declines Observed in North America and Europe

North America

(ranked in order of importance)

- Ozone
- Total biologically available nitrogen compounds. This includes wet and dry deposition of all biologically available gaseous, aerosol, and dissolved or suspended forms of nitrate nitrogen (NO_3 and HNO_3 vapor), ammonia nitrogen (NH_3), and ammonium nitrogen (NH_{4+})
- Other phytotoxic gases, including nitrogen oxides (NO_x), sulfur dioxide (SO_2), fluorine (Fl), and both peroxacetyl nitrate (PAN) and peroxyproprionyl nitrate (PPN)
- Toxic metals, especially lead, cadmium, zinc, and copper
- Nutrient and acidity-determining cations and anions in wet and dry acid deposition, including potassium, sodium, magnesium, calcium, hydrogen, nitrate, sulfate, phosphate, and chloride
- Growth-altering organic chemicals such as ethylene and aniline

Note: This list is biased toward low elevation forests. If it were to include only high elevation forests, the order of importance would change. Nitrogen saturation would come first, followed by heavy metal fallout, ozone and other photochemical oxidants, and acid deposition.
Source: A. Bartuska *et al.*, 1985, Reference 21.

Western Europe

- Ozone
- Acid deposition, particularly acid mists and fog
- Other gaseous pollutants such as nitrogen oxides and sulfur dioxide
- Excess nitrogen deposition
- Growth-altering organic chemicals

Source: A. Bartuska *et al.*, 1985, Reference 21, and Peter Schütt, 1985 (personal communication).

Eastern Europe

- Gaseous pollutants like sulfur dioxide and nitrogen oxides
- Ozone and other photochemical oxidants
- Acid deposition, particularly acid mist and fog
- Heavy metals

Note: Since the declines in Eastern Europe are due generally to the classic pollutants, sulfur dioxide plays a much more important role.
Source: Compiled by World Resources Institute from various sources.

toms can be reproduced under controlled conditions, then perhaps the twisted knot of cause and effect can be unraveled, at least a little.

Closely linked to the lab work is an extensive field research program. This is concentrated in four regions: the low mountain ranges of northern Germany; the Schwarzwald (Black Forest) in southwest Germany; and the Fichtelgebirge and Bayerischer Wald in Bavaria (southeastern Germany) (97).

In the first region (low mountains of northern Germany), research efforts are focusing on the connection among pollution deposition, soil acidification, and the changes generated in soil biology and root formation. Supplemental studies include: influence of atmospheric pollutants on changes in ground vegetation, soil biology, and microbial decomposition processes in the soil.

Research efforts in Region 2 (Black Forest) are concentrating on "silvicultural measures aimed at prevention and therapy (e.g., fertilization and thinning) as well as their effects on the development of tree stocks, metabolism, humus layers and fine root systems." The following pollutants are also being measured: SO_2, NO_x, O_3, and PAN.

In Region 3 (Fichtelgebirge), efforts are concentrated on questions regarding soil chemistry, plant nutrition, and whole plant physiology. In addition, fertilization experiments are being carried out along with gas-exchange studies (water status, transpiration, and photosynthesis) on badly damaged spruce.

The fourth part of the research program (Bavarian Forest) is centered on the development of remote sensing methods for the identification and categorization of damage. The end result will be a "balance sheet" of the structure and nature of affected stands. Soil studies are also underway to shed light on the influence of gaseous SO_2 on sulfur accumulation in the soil (98).

The official program is well underway with the first comprehensive results expected in two years. There are fringe benefits to such a large-scale centrally coordinated research program—West German scientists are being forced to work in interdisciplinary teams, something they are unaccustomed to doing. It has been recognized that the traditional piecemeal methods of scientific investigation will not suffice. When it comes to *Waldsterben*, only a comprehensive ecosystem approach is most likely to yield useful data. Comments Dr. Bernhard Rami of the Ministry for Research and Technology, "since the combination of pollutants is more damaging than individual elements, we have multiple teams of researchers—air chemists, soil scientists, water specialists, plant physiologists, meteorologists, and plant pathologists—working on the problem" (99).

Since 1980, increased evidence of forest damage in Europe and North America has led to a rapid expansion of research in this crucial area. The U.S. Forest Service and the Environmental Protection Agency (EPA) have formed a joint research program under the umbrella of the National Acid Precipitation Assessment Program. This newly established effort will channel an initial $4.8 million into two major initiatives: 60 percent has gone for research on northeastern forests—to be administered by the Northeastern Forest Experimental Station (U.S. Forest Service); the remaining 40 percent supports research on southeastern forests, supervised by the Southern Appalachian Research Resource Management Cooperative (SARRMC). The research is concentrating on spruce-fir forests in the Northeast and Southeast; commercial pine forests in the Southeast, and mixed hardwood forests in the Northwest and Southeast. In fiscal year 1986, the funds will nearly double to $8 million, $4 million for each center (100).

The research plan has three major goals:

1. "To characterize and describe the current state of forests where air pollution effects are suspected to occur (as well as control areas) and to search for possible correlations of damage by airborne pollutants;
2. "To develop conceptual models of the cause and effect relationships between forest damage and air pollutants, and to use those conceptual models to design experiments, and then implement them to test different hypotheses of damage; and
3. "To refine and develop quantitative models of stand dynamics to predict the responses of forest stands under different air quality scenarios and to extrapolate the current responses of forests across broad spatial regions" (101).

What this means is that specific research efforts must do two things within the general framework: 1) characterize the ecosystem-at-risk, including determination of the quality and quantity of deposition, analysis of key site variables like soil condition, tissue chemistry, pests and pathogens, and a complete documentation of site history; and 2) institute field and greenhouse experiments to identify plant responses to various airborne pollutants and other variables like climate—both singularly and in combinations (102).

In addition to the $4.8 million research package, another $2.5 million has been earmarked for a National Vegetation Survey (coordinated by the Forest Service) that will attempt to assess the extent of productivity losses and visual symptoms of decline in U.S. forests thought to be at risk from air pollution (103). The program will also establish long-term monitoring plots to serve as "early warning stations."

Perhaps most important of all, there is general agreement among scientists that after the initial research, attention will have to shift more toward the combined or additive effects of "multiple pollutants." And these "interaction studies" will require, by far, the greatest output of effort and money as the search for the causes of the North American and European forest declines moves into its final phases.

SEEING THE TREES THROUGH THE FOREST: GRAPPLING WITH THE POLICY IMPLICATIONS OF FOREST DECLINE

It stands to reason that a disease syndrome as complex and widespread as *Waldsterben*, requires a comprehensive and multi-staged response.

So far, the international response to the threat of continued transboundary airborne chemical pollution has been neither comprehensive nor multi-staged. Since "acid rain" is still regarded as the grim reaper of the environment—thereby ignoring dozens of other harmful chemical compounds—control efforts have centered on sulfur dioxide, and to a certain extent, on nitrogen oxides. It is increasingly clear that whatever combination of pollutants is killing North American and European forests, they are not the same agents that are acidifying lakes and streams in those same countries. Important as it is to control acid rain because of its deadly effects on freshwater resources, terrestrial ecosystems, and the built environment, it should be recognized that battling the agents of forest decline is a much more complicated and far-reaching process. West German scientists investigating *Waldsterben* have identified as many as 160 different possible causative factors (104).

There is little doubt that sulfur dioxide and nitrogen oxide emissions are enormous, but they are only part of the problem. In 1980, roughly 115 million metric tons of anthropogenic sulfur dioxide were belched into the northern hemisphere by the industrialized countries in Western and Eastern Europe (including the USSR), Scandinavia, and North America. (See Table 12.8.) That same year, nitrogen oxide emissions totaled 21–23 million metric tons for the United States, 1.8 million metric tons for Canada, and 9–10 million metric tons for Western Europe (105). Unlike sulfur emissions, which are expected to drop significantly by 1995, nitrogen oxides are projected to increase still further by as much as 25 percent for North America and 5–21 percent for Western Europe by the year 2000 (106).

Table 12.8 The Twelve Largest Producers of SO_2 and Sources, 1980

	Annual SO_2 Emissions (thousands of metric tons)	Sulfur Deposition (percent)		
		Foreign	Domestic	Undecided
Top Twelve				
USSR	25,000	32	53	15
United States	24,100			
China	12,000			
United Kingdom	4,680	12	79	9
Canada	4,516	50[a]	50	
East Germany	4,000	32	65	3
Italy	3,800	22	70	8
France	3,270	34	52	14
West Germany	3,200	45	48	7
Czechoslovakia	3,100	56	37	7
Yugoslavia	3,000	41	51	8
Poland	2,755	52	42	6
EEC Total	17,596			
Others				
Spain	2,730[b]	18	63	19
Hungary	1,633	52	42	4
Finland	595	55	26	19
Sweden	496	58	18	24
Norway	137	63	8	29

Notes:
a. Rough estimate.
b. 1985 data.
Source: Data from EMEP, 1981, and the U.N. Economic Commission for Europe (ECE), 1982.

The progress made in Europe to curtail SO_2 emissions to date is due in large measure to the U.N. Economic Commission for Europe's (ECE) Convention on Long Range Transboundary Air Pollution (LRTAP). Signed in Geneva in 1979, the Convention did not come into effect until March 1983, but as of April 1985, 30 countries had ratified it (including the United States and the USSR) (107). Although the LRTAP has been criticized for not having real teeth—until recently it had no timetable for reducing SO_2 emissions—the Convention has been credited with beefing up Europe's pollution data gathering network: there are now 88 monitoring stations operating in 23 countries (108). Transboundary pollution issues were given a badly needed nudge during the 1982 Stockholm Conference on the Acidification of the Environment. At this critical meeting it was concluded that anthropogenic emissions of sulfur and nitrogen compounds were primarily responsible for acid deposition, that a decrease in emissions over large industrialized regions would lead to an "approximately proportionate" decrease in acid deposition, and that the technology was already commercially available to radically reduce pollution loads (109).

The Stockholm Conference was also noteworthy in that the West German Government announced a major policy shift: literally, from putting the brakes on further pollution abatement efforts to stepping on the accelerator by insisting on new and much more comprehensive control legislation. The reason was simple: reports that West Germany's forests were dying from air pollution, and the subsequent political fallout prompted the "change of heart" in Stockholm.

As part of the Nordic initiative to speed up compliance with the ECE Convention, delegates from ten countries gathered in Ottawa in 1984 and agreed to reduce SO_2 emissions by at least 30 percent by 1993 (using 1980 emissions as the baseline). Some countries even agreed to higher reductions. (See Table 12.9.) The group was dubbed the "30 Percent Club," and as of April 1985, 19 countries had agreed to lower their emissions of sulfur, along with unspecified reductions in other pollutants, mainly nitrogen oxides (110).

At Helsinki in July 1985, LRTAP was finally given some real substance. A protocol mandating definite SO_2 reductions of 30 percent by 1993—under the same terms as the 30 Percent Club—was opened for signature. It was immediately signed by the 21 members (representing 19 countries) of the 30 Percent Club, giving it more than enough signatories to bring it into force in October 1985 (111).

Still, two of the largest emitters of both SO_2 and NO_x, Great Britain and the United States, refused to sign the protocol on the grounds that scientific uncertainty made further reductions problematic.

The European Economic Community (EEC) has also been moving to reduce pollution loads in member countries. In 1983, the Commission of the European Community proposed a Council Directive calling for significant cuts in three categories of polluting emissions by 1995: 60 percent reduction for SO_2, 40 percent for NO_x, and 40 percent for dust. Large fossil-fuel-burning power stations were the main targets (112).

Such plants account for more than 80 percent of SO_2 emissions and 40 percent of NO_x emissions within the European Community. The Commission calculated that additional costs for the slated reductions would be less than 10 percent of total production costs (113). The OECD estimated that the damage from acid rain alone costs the European Community somewhere between $1.4 and $4.2 billion a year (114).

The Commission has also recommended that all member countries switch to unleaded petrol by 1989 and that catalytic converters (with U.S. standards) be in full use within the Community by 1995 (115).

Table 12.9 The 30 Percent Club, as of May 1985[a]

	Date of Accession	Exceptions
Austria	June 1983	
Canada	June 1983	50% by 1994
Denmark	June 1983	40% by 1995
Finland	June 1983	
Federal Republic of Germany	June 1983	50% by 1993
Norway	June 1983	50% by 1994
Sweden	June 1983	
Switzerland	June 1983	
France	Mar. 1984	50% by 1990
Netherlands	Mar. 1984	50% by 1995
Belgium	June 1984	
Bulgaria	June 1984	
Byelorussia (Soviet Socialist Republic)	June 1984	
German Democratic Republic	June 1984	
Liechtenstein	June 1984	
Luxembourg	June 1984	
Ukraine (Soviet Socialist Republic)	June 1984	
USSR	June 1984	
Czechoslovakia	Sept. 1984	
Italy	Sept. 1984	
Hungary	April 1985	

Note: a. Membership has agreed to reduce SO_2 emissions by 30 percent of the 1980 levels.
Source: Earthscan, 1985. Reference 2.

In June of 1985, at the urging of West Germany, the Commission met to discuss the adoption of U.S. emission standards on all new vehicles throughout the Community. Typically, resistance from the other three big car producers—Italy, France, and Great Britian—scotched plans to introduce more stringent, U.S. type controls on motor vehicles. The resulting compromise placed emission controls only on larger vehicles (two liters or more). As of 1988, all large new cars will have to be fitted with catalytic converters and will not be permitted to emit more than 25 grams of carbon monoxide, 6.5 grams of hydrocarbons, and 3.5 grams of NO_x per test. Small (under 1.4 liters) and medium-sized vehicles (1.4 to 2 liters) will be regulated beginning in 1992, but these constitute the bulk of Europe's road traffic. Lead-free petrol will have to be available throughout the Community by 1993, but its introduction will begin much earlier (116).

Disappointed with the outcome, West Germany decided to step up its own program of pollution abatement. New legislation provides tax incentives for those who are willing to retrofit their cars with catalytic converters, and unleaded petrol introduced in 1984 will be commonplace by 1988 (117).

West German regulators have not stopped with mobile sources of pollution; emissions from fossil-fuel-fired power plants and industrial complexes will also be reduced. By the early 1990s, NO_x and SO_2 emissions will be slashed by 70 percent (over 1980 levels): SO_2 will drop from 3 million metric tons (1982) to 1.2 million metric tons by 1993, while NO_x will go from 1 million metric tons (1982) to 0.3 million metric tons by 1993 (118).

Officials are even considering imposing speed limits of 80–100 km/hr on the autobahns (freeways) to reduce pollution. But this is a highly emotive issue. "Autobahn speed limits arouse the same kind of passions in West Germany as gun control laws do in the United States," noted the *New York Times* in 1984. Regardless of the state of Germany's forests, imposing speed limits is likely to be a long and difficult route.

Despite this impressive record of recent regulations, the Federal Republic is still plagued by the anomaly of Buschhaus, a huge coal-fired power station at Helmstedt near the East German border. Commissioned in April 1985, the plant burns lignite with a high sulfur content (3.5 percent). Each year its 307-meter-high stack will emit 125,000 metric tons of SO_2, or 18 metric tons per hour (119). For technical and "legal" reasons, it was allowed to operate virtually without pollution controls, even though the country is clearly making important strides in reducing pollution loads.

Important as all these steps are in bringing pollutants "under the heel" of regulation, how far such agreements as the 30 Percent Club and LRTAP will go toward solving even the problem of acid deposition is uncertain. In any case, there will be no noticeable changes for ten years; it will take that long for control measures to have a major impact. There is also inbuilt government inertia when it comes to implementing and paying for pollution control technologies. Reducing air pollution is still regarded as an unnecessary economic sacrifice, hampering development and growth.

The existing quagmire of conflicting national laws and policies spills over into regional (i.e., European Economic Community) or international attempts at curbing emissions of polluting substances. Current national and international controls on pollution are inadequate to deal with the array of airborne chemicals responsible for forest dieback and death. Such inadequacy is reinforced by scientific uncertainty and indecision, which in turn fosters frustration and paralysis at the policy level. This "vicious circle" is made infinitely more complicated by the transboundary nature of air pollution, especially since national control policies will, in many cases, have only a cosmetic effect.

This is certainly true for North America, where Canada and the United States are locked in a dispute over the issue of acid rain. Canadians claim that many of their 50,000 acid sensitive lakes and stands of dying sugar maples are damaged by pollution imported from the United States.

Because of the Clean Air Act, the United States is ahead of Europe and Canada when it comes to controlling emissions from vehicles; two-way catalytic converters, which reduce emissions of hydrocarbons and carbon monoxide (but not NO_x), and low lead petrol have been required since 1975. Lead-free petrol will be required in 1986. Great efforts have also been made to control emissions from stationary sources. Despite the Tennessee Valley Authority's (TVA) successful effort to cut its SO_2 emissions in half (about one million tons), further progress to curtail national emissions has been put in the slow lane, especially in regard to the retrofitting of fossil-fuel-fired power plants in the Midwest. And it is these emitters—particularly the belt of large coal-fired power plants running through Indiana, Ohio, and Pennsylvania—that are sending their polluting gases over the Canadian border.

With little hope for a bilateral agreement to reduce polluting emissions, the disgruntled Canadians have taken unilateral action to at least put their own house in order. In March 1985, Canada announced that it would halve its domestic SO_2 emissions by 1994 (from 4.6 million to 2.3 million tons) at a cost of around $300 million. At the same time, officials decided to reduce NO_x emissions by introducing new vehicle emission standards (equivalent to those in the United States) to be effective beginning September 1, 1987. Unleaded petrol is already available in Canada, but a complete switch is planned for sometime in 1988 when catalytic converters will be required on all new vehicle models (120).

Dr. Ellis Cowling of North Carolina State University has drawn up a list of scientific generalizations regarding air pollution and its various effects that bear directly on policy decisions: 1) combustion of fossil fuels is the single most important source of air pollutants; 2) the concentration and deposition of primary air pollutants decrease progressively with increasing distance and time after emission from any particular source; 3) the concentration and deposition of secondary pollutants are a complex function of meteorological, seasonal, altitudinal, temporal, geographical, and other factors; 4) the elapsed time between emission and deposition varies with the pollutant in question but ordinarily ranges from a few minutes or hours to a maximum of four or five days; 5) this time is sufficient to disperse pollutants over both short distances (0–500 km) and long distances (500–2,000 km); 6) for these reasons no state or province can control the quality of air within its own borders without cooperation by other nearby states or provinces; 7) the atmosphere over most industrial regions is very well mixed and the distance between most sources of air pollution is much smaller than the average distance of dispersal from any given source; 8) thus, pollutants rarely, if ever, occur alone—they frequently react with each other forming new chemical products that can be additive, synergistic, or antagonistic in their effects; 9) for many pollutants with biological effects there is no distinct "threshold dose" or safe concentration below which we are certain there will be no adverse effects; 10) therefore significant decreases in emissions of SO_2, NO_x, and hydrocarbons (VOC) are very likely to have significant and simultaneous beneficial effects on human health, visibility, materials damage, surface water quality, and both crop and forest productivity (121).

This implies a rather broad-based approach to pollution control involving the reduction of emissions from both stationary and mobile sources. Cowling's view was supported by a contribution from Dr. Ann Bartuska, of North Carolina State University, to the latest *Assessment of Acid Deposition and Its Effects*. The report concluded that sulfur dioxide is not the only airborne chemical that is injurious to the environment, and that "if ozone and/or biologically available nitrogen compounds and/or toxic metals prove to be among the airborne chemicals that have significant detrimental effects on forests, it may be desirable to decrease regional emissions of nitrogen oxides and volatile organic compounds either simultaneously with or independently of future changes in emissions of SO_2" (122).

Current control strategies throughout much of Europe, while dealing successfully with SO_2 and to some extent with NO_x from stationary sources, have almost totally ignored volatile organic hydrocarbons, organic chemical compounds, heavy metals, and nitrogen-ammonia deposition from both stationary and mobile sources. The United States, on the other hand, has successfully lowered vehicle emissions of hydrocarbons, lead, and NO_x, but has been prevented by political considerations from further controlling the emissions of these same substances from power plants and industrial processes. Having reduced SO_2 emissions by an impressive 36 percent between 1973 and 1983, U.S. policy-makers are now stalled. The Reagan Administration has consistently delayed attempts to further reduce current SO_2 pollution loads.

Dr. Bartuska highlighted the dilemma that forest death and decline poses for policy-makers: "1) atmospheric depositions of biologically available nitrogen compounds and heavy metals are more likely to be important in high elevation rather than low elevation forests, and 2) ozone, either alone or in combination with other toxic gases, is the chemical most likely to be important in low elevation forests" (123).

What this means is that no single pollutant control strategy is likely to be effective in dealing with forest decline—it will take nothing less than a total integrated mix of strategies and technologies, tailored for each region, to significantly improve air quality in Europe and North America.

From a technological point of view, a package of controls must be developed and put in place. The technologies for reducing harmful emissions of pollutants are, by and large, already on the shelf. Like any sensible shopper, policy-makers will have to select the right combination of these technologies for the greatest impact at the least cost.

Technological Solutions to Political Problems

There are many technological routes to take in reducing airborne pollution; the big stumbling block is the cost and social consequences of their actual introduction. In Western Europe and North America, broad-based political considerations often override environmental concerns.

Fuel switching

One of the simplest methods of reducing SO_2 pollution is to switch to fuels with a lower sulfur content. The sulfur content in fossil fuels varies from 0.2 to 5.5 percent by weight. Switching from a high sulfur coal, for example, to a lower sulfur coal can have immediate benefits for the environment (124). Such a policy does, of course, have harmful economic impacts in regions mining high sulfur coal.

Coal cleaning

In a number of countries, particularly Scandinavia, Japan, and the United States, coal is physically and chemically pre-treated to remove some of the sulfur. The process is well established and rather inexpensive. Physical cleaning, which includes grinding and washing, adds only $4–9 per ton to the price of coal in the United States (125).

Oil desulfurization

This is a widely applied method and is similar to coal cleaning in that it is also a pre-combustion technique. The oil is pre-treated with hydrogen, which partially removes the sulfur by combining with it to form hydrogen sulfide gas (126).

Flue-gas desulfurization (FGD)

FGD is a post-combustion process that involves spraying the hot exhaust gases with lime or limestone before they are blown up the stack. Commonly referred to as "scrubbing," the process involves the injection of lime, either wet or dry. It combines with the sulfur to form gypsum, which can then be sold as roadbed filler or for other construction purposes. This technology is well developed; there are about 1,000 plants equipped with FGD worldwide, 100 of them in the United States (127).

Fluidized bed combustion

Although this technique has been in use for some time, the latest advances are noteworthy. New fluidized bed boilers burn not only all kinds of fossil fuels but a wide variety of bio-fuels as well (i.e., peat, garbage, wood wastes, sawdust, etc.). The newer models are extremely fuel efficient—with combustion efficiencies of almost 99 percent—and are able to remove 80–95 percent of SO_2 and NO_x with significant cuts in heavy metals as well. This is done *in situ* by the injection of lime or limestone into the combustion bed.

The Limestone Injection Multi-Staged Burner (LIMB) is an example of technology developed in the United States to burn multi-fuels and remove multiple pollutants, although there are other versions of this under development, or already commercially available, in Europe and Japan. LIMB has been estimated to cost $30–40 per kilowatt (128).

Decreasing nitrogen oxides

Nitrogen oxides can be decreased in power plants and industrial processes through fairly well established technologies: using low NO_x burners, modifying boilers, and through selective catalytic reduction (SCR) of NO_x in the combustion gases (also called "fuel gas treatment").

Since vehicles contribute 40–80 percent of all NO_x emissions (depending on the country), it is imperative that all cars be fitted with three-way catalytic converters (which, in turn, require very low lead or lead-free petrol in order to function). Catalytic converters, in combination with combustion modifications in engine design, can greatly decrease NO_x, carbon monoxide, and hydrocarbons in vehicle exhaust. The new three-way catalyst now under development can decrease these pollutants by 90–95 percent, but its general introduction is still several years away. Another technological breakthrough—the Lean Burn Engine—is estimated to reduce NO_x by 75–90 percent, but it will not be commercially available for about ten years (129).

WHAT MUST BE DONE

Although it appears unlikely that a generally agreed upon public consensus about decreasing emissions of major pollutants, other than lead, will emerge during the next 2–3 years, two general points remain clear:

1. The American and European policy debates about sulfur dioxide have obscured the importance of other pollutants—namely hydrocarbons, heavy metals, NO_x, organic chemical compounds, and other secondary toxic gases like ozone and PAN. All of these warrant increased regulatory attention.
2. Acid rain has been used as a catchall phrase by environmentalists pressing for changes in pollution control strategies and by governments as an excuse to do nothing or very little. This continuing controversy camouflages the real picture: pollution has multiple causes and multiple effects, acidification is just one of many.

The search for a way out of the maze is complicated by inconsistent and inadequate monitoring methods that generally look at only one or two pollutants, like SO_x or NO_x, differences in the interpretation of data, and an absence of coordinated research between countries. This is made worse by intramural bickering among different scientific camps as to the exact relationship between pollution and environmental damage. Furthermore, the debate has often been tainted by nationalism, with scientists falling prey to assessments colored by national interests. Great Britain and the United States are prime examples of this tug-of-war between science fact and science fiction.

At present, the path recommended by the Commission of the European Community is probably the best model for tackling the specter of multiple pollutants and resulting forest death. The speed of implementation may be too slow, but the program, if eventually adopted, is comprehensive and transboundary. In order to control pollutants, countries need integrated approaches. The following measures need to be legislatively worked out and implemented by the early 1990s:

1. Three-way catalytic converters should be fitted on all new passenger cars, thereby necessitating the widespread introduction of lead-free petrol. In some cases, like West Germany, speed limits may also be required. (This, of course, does not apply to the United States.)
2. New emission standards for refineries, petrochemical complexes, and chemical fertilizer plants to lower emissions of hydrocarbons and other organic chemicals, as well as airborne nitrogen compounds.
3. Stricter controls on fossil-fuel-fired power stations. New plants should have lower stacks, and multi-staged combustion burners and/or fuel-gas cleaning processes that eliminate not only SO_2, but also NO_x, heavy metals, and particulates (i.e., dust, soot, ash, etc.).

In the interim period, fuel switching should be encouraged.

4. Stricter controls on metal smelters that produce high amounts of SO_2 and particularly heavy metals like lead, cadmium, zinc, copper, and nickel.
5. Setting standards for the application of nitrogen fertilizers on agricultural land and in forests.

All of these measures require more research and a rigorous cost-benefit analysis. Although the actual mechanisms of destruction may never be completely understood, in a few years, scientists will know much more about the role of air pollutants in the growth and development of forests, and will be in a better position to make more specific recommendations. By introducing comprehensive measures to decrease emissions of SO_2, NO_x, and VOC, in efforts to control forest decline, policy-makers will also be improving the situation as regards to human health, materials destruction, acidification of lakes and rivers, and polluted air in general.

To achieve these multiple benefits it is vitally important that these recommendations be dealt with as a package—the "one pollutant at a time" regulatory approach will not suffice to tackle the problem in time. Money will have to be spent where it will do the most good. This may mean that certain heavy point sources of pollution in sensitive areas must be identified and controlled more than others. As for Europe, it is critical that a continent-wide switch to catalytic converters and lead-free petrol be carried through as planned. The big hitch is that Eastern Europe—particularly East Germany, Poland, and Czechoslovakia—lack the hard cash to invest in many of these measures. So transboundary pollution will continue to be a nagging and perhaps even a bitter issue, dividing Eastern and Western Europe. The same is true for North America where the United States and Canada are at loggerheads over transboundary pollution and acid rain.

No doubt the costs for such a long-range and integrated program will be high. The U.S. Office of Technology Assessment (OTA) estimates that reducing sulfur dioxide emissions by nearly half (10 million tons) from existing sources, would cost $3–4 billion a year, increasing electricity rates by 2–3 percent. If NO_x were figured in, the costs might be as high as $6 billion a year (130).

The solution may ultimately depend on narrowing the dichotomy between rhetoric and reality, on persuading governments to invest in sound environmental management plans, and on balancing short-term interests against long-term policy. It also depends on recognizing that although the costs of controlling pollution are high, the costs of not doing so could well be astronomical. It's a matter of whether we start spreading the burden around now, or leave the costs and consequences to our children.

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World Resource Data Tables **Part IV**

1. Basic Economic Indicators

Employment, production, and price statistics are three basic economic indicators that are used in most countries to monitor levels of, and short-term changes in economic activity.

Gross National Product (GNP), perhaps the most important indicator of economic growth, measures the total market value of goods and services produced in a country in a year, taking into account trade with other countries. There are two major problems with using GNP as a broader measure of economic development: the first is comparability among countries; the second is the extent to which economically valuable activities and resources are covered.

The GNP figures used here have been taken from World Bank data files and publications. They are usually more accurate for countries in which economic transactions (trade in goods, services, and labor) go through a marketplace and can be accurately recorded. Data for many developing countries, where markets are not as well developed or where data collection systems are rudimentary, require extensive imputations. In all countries a fraction of economic activity occurs in black markets and its value is not adequately represented in official statistics. Countries at war or suffering civil strife, such as Lebanon, Democratic Kampuchea, Afghanistan, Iran, and Iraq, do not report GNP data, or the figures they have are incomplete. GNP data for non-market economies such as the Soviet Union, Viet Nam, and Cuba are very difficult to calculate and interpret, and, except for Hungary, are omitted from Table 1.1.

Comparing the GNP of one country to another requires the use of a common currency (most often, U.S. dollars) and a common base year. However, currency exchange rates do not accurately reflect the relative purchasing powers of currencies. For example, the price of labor services (such as haircuts) relative to those of commodities that enter international trade (such as wheat) differs systematically between high- and low-income countries. GNP estimates converted to dollars using currency exchange rates substantially overstate international differences in real living standards. The procedures used by the World Bank to calculate GNP in constant U.S. dollars are described in the *World Development Report 1985*. Updated GNP figures are available in the latest issue of the *World Bank Atlas*.

The problem of coverage is more difficult to overcome. GNP tells us little about a nation's wealth in human and natural resources, and changes in a nation's natural resource assets are not adequately accounted for. Rapid depletion of ground-water, fisheries, forests, soils, and other natural resources reduce a nation's potential future income. The current economic gain from the water used, the fish caught, the wood sold, and the crops grown is treated as a positive contribution to GNP, but the depletion of the value of the natural resource asset is not subtracted. Using current GNP figures as indicators of long-term economic opportunities, therefore, can be very misleading.

The size of the labor force, presented in Table 1.2, is an important measure of employment opportunity in a country. The total labor force is composed of all persons who work to produce economic goods and services, including the unemployed. Current estimates are based on information available to the International Labor Organization (ILO) in the mid-1970s. Because of severe economic recessions and substantial migration of workers across international borders, the figures for some countries may no longer be reliable.

World commodity prices presented in Table 1.3 (also from World Bank sources) are for commodities that are traded in world markets. These same materials are traded locally within countries at prices that may vary widely from those of global markets because of transportation costs, tariffs, trade restrictions, and other factors. Many important commodities, such as wild plants and animals, are traded less frequently and sometimes illegally. Data for these commodities are not included here.

The data on international commodity price trends reflect market prices converted to U.S. dollars and deflated for inflation. The World Bank uses the Manufacturing Unit Value (MUV) Index as a deflator because it reflects changes in the price of goods that developing countries buy on the world market. The price trend for 33 non-fuel commodities, for example, has been one of sharp decline. Using the MUV deflator, the combined price index of these commodities stood at 160 in 1970, at 100 in 1977–79, and at 84 in 1984. This represents a halving of the purchasing power of raw materials in terms of manufactured goods.

Table 1.1 GROSS NATIONAL PRODUCT, 1960–83

	Gross National Product 1983		Average Annual Growth Rate of Real GNP (percent)		Distribution of Gross Domestic Product 1983 (percent)		
	Total (millions of $US)	Per Capita ($US)	1960–75	1975–83	Agriculture	Industry	Services
WORLD							
AFRICA							
Algeria	49450	2400	5.8	6.0	6	54	40
Angola	X	X	2.8	0.3	X	X	X
Benin	1110	290	2.9	5.3	40	14	47
Botswana	920	920	10.1	11.7	X	X	X
Burkina Faso	1210	180	2.8	3.3	41	19	40
Burundi	1050	240	4.0	3.9	58	16	26
Cameroon	7640	800	4.2	7.3	24	32	45
Cape Verde	110	360	X	7.5	X	X	X
Central African Rep	690	280	2.3	-0.2	37	21	42
Chad	X	X	0.7	-9.5	X	X	X
Comoros	X	X	5.1	6.0	X	X	X
Congo	2180	1230	5.2	9.6	7	55	38
Djibouti	X	X	X	1.8	X	X	X
Egypt	31880	700	4.5	8.6	20	33	47
Equatorial Guinea	X	X	0.7	X	X	X	X
Ethiopia	4860	140	4.3	3.1	48	16	36
Gabon	2950	4250	7.3	7.4	X	X	X
Gambia	200	290	6.1	1.5	X	X	X
Ghana	3980	320	2.4	1.1	53	7	40
Guinea	1740	300	3.3	1.5	38	23	39
Guinea-Bissau	150	180	X	1.8	X	X	X
Ivory Coast	6730	720	7.3	3.4	27	24	50
Kenya	6450	340	7.1	5.0	33	20	46
Lesotho	670	470	8.6	4.2	23	22	55
Liberia	990	470	4.9	1.5	36	26	38
Libya	25100	7500	12.5	2.0	2	64	34
Madagascar	2730	290	2.8	-0.3	41	15	44
Malawi	1390	210	6.0	3.7	X	X	X
Mali	1110	150	3.1	3.1	46	11	43
Mauritania	720	440	4.8	2.9	34	21	45
Mauritius	1250	1150	2.8	2.7	X	X	X
Morocco	15620	750	4.9	3.5	17	32	51
Mozambique	X	X	4.5	0.1	X	X	X
Niger	1460	240	0.7	5.5	33	31	37
Nigeria	71030	760	6.4	0.3	26	34	40
Rwanda	1540	270	4.1	5.1	X	X	X
Senegal	2730	440	2.1	1.8	21	26	54
Sierra Leone	1230	380	4.1	1.8	32	20	48
Somalia	1140	250	1.7	1.2	50	11	39
South Africa	76890	2450	5.6	2.9	X	X	X
Sudan	8420	400	1.2	3.3	34	15	51
Swaziland	610	890	9.2	2.5	X	X	X
Tanzania, United Rep	4880	240	5.7	1.8	52	15	33
Togo	790	280	6.8	1.8	22	28	50
Tunisia	8860	1290	6.3	5.5	14	36	50
Uganda	3090	220	4.3	2.0	X	X	X
Zaire	5050	160	4.0	0.0	36	20	44
Zambia	3630	580	4.5	0.4	14	38	48
Zimbabwe	5820	740	5.8	4.6	11	32	57
NORTH AMERICA							
Barbados	1020	3930	6.0	2.7	X	X	X
Canada	300400	12000	5.4	1.7	3	29	68
Costa Rica	2420	1020	6.6	1.0	23	27	50
Cuba	X	X	X	X	X	X	X
Dominican Rep	8170	1380	6.4	3.9	17	29	55
El Salvador	3690	710	5.3	-2.2	20	21	59
Guatemala	8890	1120	5.7	3.0	X	X	X
Haiti	1700	320	1.3	2.9	X	X	X
Honduras	2740	670	4.4	4.1	27	26	47
Jamaica	2940	1300	4.5	-1.9	7	34	60
Mexico	168070	2240	7.5	5.1	8	40	52
Nicaragua	2690	900	5.7	-2.7	22	32	47
Panama	4070	2070	7.2	5.5	X	X	X
Trinidad and Tobago	7870	6900	3.5	4.5	X	X	X
United States	3292340	14090	3.7	2.4	2	32	66
SOUTH AMERICA							
Argentina	58560	2030	4.2	-0.8	12	39	49
Bolivia	3070	510	4.8	-1.4	23	26	52
Brazil	245590	1890	7.5	3.4	12	35	53
Chile	21890	1870	3.0	3.4	10	36	55
Colombia	38830	1410	5.6	4.0	20	28	51
Ecuador	11690	1430	8.2	4.0	14	40	46
Guyana	410	520	4.6	-2.9	X	X	X
Paraguay	4540	1410	4.8	8.3	26	26	48
Peru	18650	1040	4.5	0.7	8	41	51
Suriname	1280	3520	7.0	3.0	X	X	X
Uruguay	7390	2490	1.8	1.8	12	28	60
Venezuela	70820	4100	6.1	0.7	7	40	53

Table 1.1

	Gross National Product 1983		Average Annual Growth Rate of Real GNP (percent)		Distribution of Gross Domestic Product 1983 (percent)		
	Total (millions of $US)	Per Capita ($US)	1960–75	1975–83	Agriculture	Industry	Services
ASIA							
Afghanistan	X	X	2.0	1.5	X	X	X
Bahrain	4120	10360	X	6.4	X	X	X
Bangladesh	12530	130	1.9	4.9	47	13	40
Bhutan	X	X	X	4.0	X	X	X
Burma	6500	180	2.9	6.1	48	13	39
China	301840	290	7.1	7.1	37	45	18
Cyprus	2430	3720	7.0	7.3	X	X	X
India	190710	260	3.5	3.9	36	26	38
Indonesia	87120	560	5.7	6.8	26	39	35
Iran	X	X	11.3	-1.7	X	X	X
Iraq	X	X	6.7	17.0	X	X	X
Israel	21990	5360	8.5	3.1	6	27	67
Japan	1204270	10100	9.2	4.6	4	42	55
Jordan	4400	1710	X	10.5	8	31	61
Kampuchea, Dem	X	X	-0.2	X	X	X	X
Korea, Dem People's Rep	X	X	X	X	X	X	X
Korea, Rep	80310	2010	9.0	6.2	14	39	47
Kuwait	30290	18180	5.9	5.5	1	61	38
Lao Peoples Dem Rep	X	X	X	X	X	X	X
Lebanon	X	X	5.2	X	X	X	X
Malaysia	27760	1870	6.8	7.3	21	35	44
Mongolia	X	X	X	X	X	X	X
Nepal	2660	170	2.2	2.9	59	14	27
Oman	7070	6240	13.7	7.1	X	X	X
Pakistan	35000	390	6.2	6.6	27	27	46
Philippines	39420	760	5.4	4.9	22	36	42
Qatar	5960	21170	X	-2.8	X	X	X
Saudi Arabia	127080	12180	11.9	6.7	2	66	32
Singapore	16560	6620	9.9	8.3	1	37	62
Sri Lanka	5140	330	4.3	5.2	27	26	47
Syrian Arab Rep	16510	1680	6.4	6.0	19	25	55
Thailand	40380	810	7.8	6.0	23	27	50
Turkey	58260	1230	6.6	2.5	19	33	48
United Arab Emirates	25770	21340	X	10.8	1	65	34
Viet Nam	X	X	X	X	X	X	X
Yemen	3930	510	X	7.4	21	17	62
Yemen, Dem	1020	510	X	7.4	X	X	X
EUROPE							
Albania	X	X	X	X	X	X	X
Austria	69830	9210	4.8	2.6	4	39	58
Belgium	90540	9160	4.8	1.4	2	35	63
Bulgaria	X	X	X	X	X	X	X
Czechoslovakia	X	X	X	X	X	X	X
Denmark	58850	11490	3.8	1.5	4	23	72
Finland	50730	10440	4.6	3.1	7	33	60
France	568690	10390	5.3	2.3	X	X	X
German Dem Rep	X	X	X	X	X	X	X
Germany, Fed Rep	702440	11420	4.2	2.2	2	46	52
Greece	39210	3970	7.1	2.5	17	29	53
Hungary	23050	2150	6.2	2.8	19	42	39
Ireland	16960	4810	4.3	1.8	X	X	X
Italy	357570	6350	4.9	2.3	6	40	54
Luxembourg	4470	12190	5.0	3.8	X	X	X
Malta	1310	3710	6.6	7.7	X	X	X
Netherlands	142420	9910	4.9	1.2	4	33	63
Norway	57090	13820	4.2	3.0	4	42	55
Poland	X	X	X	X	X	X	X
Portugal	22490	2190	6.4	3.1	8	40	51
Romania	X	X	X	5.2	X	X	X
Spain	182760	4800	6.6	1.4	X	X	X
Sweden	103240	12400	3.9	0.8	3	31	66
Switzerland	105060	16390	3.9	1.7	X	X	X
United Kingdom	505610	9050	2.8	1.2	2	32	66
Yugoslavia	58520	2570	6.1	3.7	X	X	X
USSR	X	X	X	X	X	X	X
OCEANIA							
Australia	166230	10780	5.2	2.3	X	X	X
Fiji	1190	1790	6.0	3.1	X	X	X
New Zealand	24000	7410	3.9	0.4	8	33	59
Papua New Guinea	2510	790	6.0	1.2	X	X	X
Solomon Islands	160	640	X	4.8	X	X	X
ANTARCTICA							

Source: The World Bank.
X = not available
For additional information, see Sources and Technical Notes.

Table 1.2 LABOR FORCE, 1965–2000

	Total Labor Force 1983 (thousands)	Percentage of Labor Force in						Average Annual Growth of the Labor Force (percent)		
		Agriculture		Industry		Services				
		1965	1981	1965	1981	1965	1981	1965–73	1973–83	1980–2000
WORLD										
AFRICA										
Algeria	4670	59	25	14	25	27	50	1.6	3.6	4.5
Angola	1986	67	59	13	16	20	25	1.7	2.8	2.8
Benin	1751	52	46	10	16	38	38	2.1	2.0	2.7
Botswana	405	X	X	X	X	X	X	X	X	X
Burkina Faso	3927	90	82	6	13	4	5	1.6	1.5	2.1
Burundi	2141	89	84	4	5	7	11	1.2	1.6	2.5
Cameroon	4112	86	83	6	7	8	10	1.9	1.8	3.2
Cape Verde	109	X	X	X	X	X	X	X	X	X
Central African Rep	1307	93	88	3	4	4	8	1.1	1.6	2.4
Chad	1805	93	85	3	7	4	8	1.6	2.3	2.3
Comoros	140	X	X	X	X	X	X	X	X	X
Congo	563	47	34	19	26	34	40	1.9	1.8	3.8
Djibouti	X	X	X	X	X	X	X	X	X	X
Egypt	12753	56	50	15	30	29	20	2.2	2.4	2.3
Equatorial Guinea	114	X	X	X	X	X	X	X	X	X
Ethiopia	13676	86	80	6	7	8	13	2.2	1.4	2.2
Gabon	268	X	X	X	X	X	X	X	X	X
Gambia	312	X	X	X	X	X	X	X	X	X
Ghana	4719	61	53	16	20	23	27	1.6	2.0	3.8
Guinea	2376	87	82	7	11	6	7	1.2	1.3	2.4
Guinea-Bissau	182	X	X	X	X	X	X	X	X	X
Ivory Coast	4338	87	79	3	4	10	17	4.2	3.8	3.3
Kenya	6903	84	78	6	10	10	12	3.2	2.9	4.0
Lesotho	743	92	60	3	15	5	25	1.7	1.9	2.5
Liberia	785	78	70	11	14	11	16	2.0	3.9	2.8
Libya	832	42	19	20	28	38	53	3.6	4.3	4.3
Madagascar	4544	92	87	3	4	5	9	1.9	1.7	3.0
Malawi	2992	91	86	4	5	5	9	2.4	2.8	2.8
Mali	3999	93	73	4	12	3	15	2.2	2.0	2.6
Mauritania	538	90	69	4	8	6	23	1.9	2.4	2.0
Mauritius	374	X	X	X	X	X	X	X	X	X
Morocco	5938	60	52	15	21	25	27	1.6	2.8	3.1
Mozambique	4173	77	66	10	18	13	16	2.2	3.0	2.9
Niger	1794	94	91	1	3	5	6	2.4	3.0	3.1
Nigeria	31436	67	54	12	19	21	27	1.8	2.0	3.3
Rwanda	2718	94	91	1	2	5	7	2.7	3.0	3.2
Senegal	2491	82	77	6	10	12	13	1.7	2.2	2.6
Sierra Leone	1383	75	65	14	19	11	16	0.7	1.2	1.7
Somalia	1994	87	82	5	8	8	10	3.8	2.0	1.7
South Africa	11433	32	30	30	29	38	41	2.7	3.2	2.9
Sudan	6158	84	78	7	10	9	12	2.5	2.5	2.9
Swaziland	273	X	X	X	X	X	X	X	X	X
Tanzania, United Rep	7909	88	83	4	6	8	11	2.5	2.5	3.1
Togo	1159	81	67	10	15	9	18	2.2	1.9	2.9
Tunisia	1646	53	35	20	32	27	33	1.4	2.9	2.9
Uganda	5860	88	83	5	6	7	11	3.0	1.7	3.4
Zaire	12717	81	75	10	13	9	12	1.8	2.2	3.0
Zambia	2263	76	67	8	11	16	22	2.3	2.1	3.3
Zimbabwe	2641	67	60	12	15	21	25	2.7	1.4	4.4
NORTH AMERICA										
Barbados	118	X	X	X	X	X	X	X	X	X
Canada	10695	11	5	33	29	56	66	2.7	2.0	1.1
Costa Rica	809	47	29	20	23	33	48	3.6	3.6	2.8
Cuba	3079	35	23	24	31	41	46	1.0	2.1	1.7
Dominican Rep	1681	64	49	13	18	23	33	2.7	3.2	2.8
El Salvador	1637	59	50	18	22	23	28	3.2	2.8	3.4
Guatemala	2407	64	55	16	21	20	24	2.9	3.0	2.9
Haiti	3091	77	74	7	7	16	19	0.7	1.5	2.0
Honduras	1206	68	63	12	20	20	17	2.4	3.3	3.5
Jamaica	824	34	35	25	18	41	47	0.7	2.6	2.6
Mexico	21961	50	36	21	26	29	38	3.1	3.1	3.2
Nicaragua	898	57	39	16	14	27	47	2.8	4.0	3.8
Panama	692	46	33	15	18	39	49	3.1	2.6	2.4
Trinidad and Tobago	481	23	10	35	39	42	51	1.8	1.2	2.3
United States	107136	5	2	36	32	59	66	1.9	1.7	0.9
SOUTH AMERICA										
Argentina	10691	18	13	34	28	48	59	1.4	1.0	1.4
Bolivia	1966	58	50	20	24	22	26	1.8	2.5	2.8
Brazil	41406	49	30	17	24	34	46	2.5	3.1	2.4
Chile	3938	26	19	21	19	53	62	1.3	2.6	2.0
Colombia	8297	45	26	20	21	35	53	3.1	2.8	2.6
Ecuador	2830	54	52	21	17	25	31	2.6	2.6	3.3
Guyana	318	X	X	X	X	X	X	X	X	X
Paraguay	1124	55	49	19	19	26	32	2.6	3.3	3.0
Peru	5705	50	40	19	19	31	41	2.4	2.9	3.0
Suriname	108	X	X	X	X	X	X	X	X	X
Uruguay	1159	18	11	30	32	52	57	0.3	0.5	0.9
Venezuela	5369	30	18	24	27	46	55	3.7	4.1	3.4

Table 1.2

	Total Labor Force 1983 (000)	Percentage of Labor Force in						Average Annual Growth of the Labor Force (percent)		
		Agriculture		Industry		Services				
		1965	1981	1965	1981	1965	1981	1965–73	1973–83	1980–2000
ASIA										
Afghanistan	5715	84	79	7	8	9	13	1.9	2.3	2.4
Bahrain	X	X	X	X	X	X	X	X	X	X
Bangladesh	32382	87	74	3	11	10	15	2.3	2.8	2.9
Bhutan	664	95	93	2	2	3	5	1.0	1.9	2.1
Burma	14936	X	67	X	10	X	23	1.3	1.4	2.2
China	480379	X	74	X	13	X	13	2.4	1.2	1.8
Cyprus	279	X	X	X	X	X	X	X	X	X
India	275894	74	71	11	13	15	16	1.8	2.1	2.1
Indonesia	52963	71	58	9	12	20	30	1.9	2.3	2.4
Iran	11560	50	39	26	34	24	27	3.1	3.0	3.5
Iraq	3529	50	42	20	26	30	32	2.9	3.1	3.7
Israel	1469	12	7	35	36	53	57	3.2	2.3	2.2
Japan	61604	26	12	32	39	42	49	1.7	1.1	0.7
Jordan	858	41	20	16	20	43	60	2.6	1.4	4.6
Kampuchea, Dem	2722	80	X	4	X	16	X	1.3	X	X
Korea, Dem Peoples Rep	8695	59	49	25	33	16	18	2.6	2.9	2.7
Korea, Rep	15732	58	34	13	29	29	37	2.9	2.7	1.9
Kuwait	401	1	2	34	34	65	64	5.3	7.1	3.2
Lao Peoples Dem Rep	1863	81	75	5	6	14	19	0.6	0.9	2.5
Lebanon	729	28	11	25	27	47	62	2.5	-0.1	2.1
Malaysia	5178	60	50	13	16	27	34	2.9	3.2	2.7
Mongolia	676	66	55	15	22	19	23	2.2	2.6	2.9
Nepal	7177	95	93	2	2	3	5	1.6	2.3	2.5
Oman	X	X	X	X	X	X	X	X	X	X
Pakistan	25375	60	57	19	20	21	23	2.3	3.2	2.7
Philippines	18314	57	46	16	17	27	37	2.1	3.0	2.5
Qatar	X	X	X	X	X	X	X	X	X	X
Saudi Arabia	2561	69	61	11	14	20	25	3.9	5.8	3.2
Singapore	1000	6	2	26	39	68	59	3.4	2.3	1.1
Sri Lanka	5594	56	54	14	14	30	32	2.0	2.1	2.2
Syrian Arab Rep	X	53	33	20	31	27	36	3.1	3.5	4.0
Thailand	22357	82	76	5	9	13	15	2.4	3.1	2.1
Turkey	19942	74	54	11	13	15	33	1.8	2.0	2.1
United Arab Emirates	X	X	X	X	X	X	X	X	X	X
Viet Nam	25782	79	71	6	10	15	19	X	X	2.9
Yemen	1701	81	75	8	11	11	14	1.0	2.1	3.3
Yemen, Dem	512	68	45	16	15	16	40	1.1	1.8	3.3
EUROPE										
Albania	1257	69	61	19	25	12	14	2.4	2.6	2.4
Austria	3430	19	9	45	37	36	54	-0.2	0.9	0.3
Belgium	4007	6	3	46	41	48	56	0.5	0.7	0.2
Bulgaria	4687	52	37	28	39	20	24	0.6	0.1	0.2
Czechoslovakia	7699	21	11	48	48	31	41	0.8	0.6	0.6
Denmark	2482	14	7	37	35	49	58	0.8	0.6	0.4
Finland	2412	28	11	33	35	39	54	0.5	0.4	0.4
France	23628	18	8	40	39	42	53	0.7	1.0	0.6
German Dem Rep	8922	15	10	49	50	36	40	0.4	0.8	0.3
Germany, Fed Rep	29525	10	4	48	46	42	50	0.3	0.8	-0.1
Greece	4138	51	37	22	28	27	35	0.1	0.9	0.5
Hungary	5207	32	21	39	43	29	36	0.5	X	0.1
Ireland	1304	31	18	28	37	41	45	0.5	1.5	1.5
Italy	21685	24	11	42	45	34	44	0.0	0.6	0.2
Luxembourg	X	X	X	X	X	X	X	X	X	X
Malta	122	X	X	X	X	X	X	X	X	X
Netherlands	5606	9	6	43	45	48	49	1.4	1.4	0.5
Norway	1568	15	7	37	37	48	56	0.6	0.7	0.6
Poland	20396	44	31	32	39	24	30	1.7	1.2	0.8
Portugal	3892	39	28	31	35	30	37	0.1	0.9	0.6
Romania	12372	58	29	19	36	23	35	0.8	0.5	0.7
Spain	13428	34	14	35	40	31	46	0.4	1.2	0.8
Sweden	3664	11	5	43	34	46	61	0.7	0.4	0.4
Switzerland	3248	10	5	50	46	40	49	1.5	0.4	0.1
United Kingdom	26241	3	2	46	42	51	56	0.2	0.4	0.2
Yugoslavia	10493	57	29	21	35	22	36	0.7	0.5	0.6
USSR	136140	33	14	33	45	34	41	0.8	1.1	0.6
OCEANIA										
Australia	6376	10	6	38	33	52	61	2.5	1.6	1.2
Fiji	227	X	X	X	X	X	X	X	X	X
New Zealand	1289	13	10	36	35	51	55	2.0	1.2	1.0
Papua New Guinea	1670	88	82	5	8	7	10	1.9	1.4	2.2
Solomon Islands	X	X	X	X	X	X	X	X	X	X
ANTARCTICA										

Sources: International Labor Organization; U.N. Food and Agriculture Organization.
X = not available
For additional information, see Sources and Technical Notes.

Table 1.3 WORLD COMMODITY PRICES AND INDEXES, 1961-84

COMMODITY INDEXES (Index Numbers Based on 1977-79 = 100)

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
ALL FOODS	93	94	130	117	92	87	86	91	100	99
BEVERAGES	70	68	67	75	71	66	63	67	68	72
CEREALS	128	143	143	138	135	144	150	156	153	126
FATS AND OILS	113	107	113	114	126	116	108	111	109	116
OTHER FOODS	103	107	241	179	90	81	83	89	122	122
NON-FOOD AGRICULTURALS	139	141	130	129	126	120	113	125	132	112
TIMBER	78	87	84	70	81	80	84	92	88	85
METALS AND MINERALS	129	127	124	149	170	173	143	156	169	160

COMMODITY PRICES (Current Prices in $US; Constant Prices in 1980 $US)

		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Cocoa	current	0.49	0.46	0.55	0.51	0.37	0.52	0.60	0.72	0.90	0.68
(kg)	constant	1.74	1.69	2.01	1.79	1.30	1.74	1.96	2.54	3.15	2.14
Coffee	current	0.79	0.75	0.75	1.03	0.99	0.90	0.83	0.83	0.90	1.20
(kg)	constant	2.86	2.74	2.74	3.65	3.47	3.00	2.74	2.90	3.13	3.80
Tea	current	1.36	1.38	1.31	1.33	1.29	1.26	1.27	1.05	0.97	1.10
(kg)	constant	4.89	5.02	4.75	4.70	4.55	4.19	4.17	3.67	3.38	3.46
Rice	current	136.5	152.8	143.3	137.7	136.3	163.2	205.8	201.6	186.9	144.0
(metric ton)	constant	491.0	557.7	521.1	488.3	479.9	544.0	677.0	707.4	649.0	454.3
Sorghum	current	42.6	45.6	48.6	48.2	47.2	51.7	50.4	46.5	50.1	51.8
(metric ton)	constant	153.2	166.4	176.7	170.9	166.2	172.3	165.8	163.2	174.0	163.4
Maize	current	45.9	51.4	54.7	55.8	55.0	59.4	49.9	49.1	53.9	58.4
(metric ton)	constant	165.1	187.6	198.9	197.9	193.7	198.0	164.1	172.3	187.2	184.2
Wheat	current	59.5	59.9	59.2	63.6	58.1	62.1	61.7	58.4	56.2	57.0
(metric ton)	constant	214.0	218.6	215.3	225.5	204.6	207.0	203.0	204.9	195.1	179.8
Sugar	current	0.06	0.06	0.18	0.13	0.04	0.04	0.04	0.04	0.07	0.08
(kg)	constant	0.21	0.22	0.67	0.45	0.16	0.13	0.14	0.15	0.25	0.26
Beef	current	0.68	0.71	0.67	0.84	0.88	1.02	1.04	1.09	1.22	1.30
(kg)	constant	2.45	2.61	2.43	2.98	3.11	3.41	3.42	3.81	4.25	4.11
Bananas	current	0.14	0.13	0.17	0.17	0.16	0.15	0.16	0.15	0.16	0.17
(kg)	constant	0.50	0.48	0.61	0.60	0.56	0.51	0.52	0.54	0.55	0.52
Coconut Oil	current	253.5	251.3	286.3	296.5	347.8	323.8	327.9	399.2	361.2	397.3
(kg)	constant	911.9	917.2	1041.1	1051.4	1224.7	1079.3	1078.6	1400.7	1254.2	1253.3
Groundnut Oil	current	330.7	274.5	268.4	315.3	323.8	296.2	283.2	270.7	331.6	378.6
(metric ton)	constant	1189.6	1001.8	976.0	1118.1	1140.1	987.3	931.6	949.8	1151.4	1194.3
Palm Oil	current	232.0	216.3	222.4	239.5	272.5	235.6	223.6	168.9	181.2	260.1
(metric ton)	constant	834.5	789.4	808.7	849.3	959.5	785.3	735.5	592.6	629.2	820.5
Soybean Meal	current	97	89	91	89	97	107	99	98	95	104
(metric ton)	constant	349	325	331	316	342	357	326	344	330	328
Fishmeal	current	131	148	145	161	190	160	134	129	172	197
(metric ton)	constant	471	540	527	571	669	533	441	453	597	621
Cotton	current	0.67	0.66	0.64	0.64	0.63	0.61	0.65	0.67	0.61	0.63
(kg)	constant	2.41	2.40	2.33	2.28	2.20	2.02	2.14	2.36	2.11	1.99
Jute	current	224.9	184.6	179.0	223.0	254.0	306.0	290.0	271.0	286.0	274.0
(metric ton)	constant	809.0	673.7	650.9	790.8	894.4	1020.0	954.0	950.0	993.1	864.4
Wool	current	1.94	1.93	2.27	2.37	1.98	2.18	1.88	1.71	1.63	1.46
(kg)	constant	6.99	7.05	8.26	8.40	6.97	7.28	6.17	6.01	5.64	4.62
Rubber	current	0.64	0.60	0.56	0.53	0.55	0.51	0.44	0.41	0.55	0.45
(kg)	constant	2.29	2.19	2.04	1.88	1.94	1.70	1.45	1.45	1.92	1.42
Logs	current	30.0	32.9	32.1	27.4	31.7	33.3	35.6	36.5	35.2	37.2
(cu. meter)	constant	107.9	120.1	116.7	97.2	111.6	111.0	117.1	128.1	122.2	117.4
Coal	current	10.06	10.08	10.06	10.14	10.22	10.24	10.57	10.80	11.48	14.77
(metric ton)	constant	36.19	36.79	36.58	35.96	35.99	34.13	34.77	37.90	39.86	46.59
Petroleum	current	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3
(barrel)	constant	5.4	5.1	5.1	4.6	4.6	4.3	4.3	4.6	4.5	4.1
Gasoline	current	X	X	X	X	X	X	30.5	26.1	19.5	21.3
(metric ton)	constant	X	X	X	X	X	X	100.3	91.6	67.7	67.2
Aluminum	current	561	527	499	523	540	540	551	564	599	633
(metric ton)	constant	2018	1923	1815	1855	1901	1800	1813	1979	2080	1997
Bauxite	current	7.5	7.5	7.5	7.5	7.5	12.0	12.0	12.0	12.0	12.0
(metric ton)	constant	27.0	27.4	27.3	26.6	26.4	40.0	39.5	42.1	41.7	37.9
Copper	current	633	644	646	968	1290	1530	1138	1241	1466	1413
(metric ton)	constant	2277	2350	2349	3433	4542	5100	3743	4354	5090	4457
Lead	current	176	154	174	278	317	262	229	240	289	304
(metric ton)	constant	633	562	633	986	1116	873	753	842	1003	959
Tin	current	2447	2471	2507	3408	3893	3574	3331	3126	3423	3673
(metric ton)	constant	8802	9018	9116	12085	13708	11913	10957	10968	11903	11587
Zinc	current	214	185	212	324	311	282	273	262	287	295
(metric ton)	constant	770	675	771	1149	1095	940	898	919	997	931
Iron Ore	current	11.5	10.8	10.1	10.1	10.1	9.9	8.7	8.4	8.4	9.3
(metric ton)	constant	41.4	39.4	36.7	35.8	35.6	33.0	28.6	29.5	29.2	29.3
Manganese Ore	current	0.87	0.86	0.81	0.68	0.75	0.76	0.72	0.62	0.52	0.54
(10 kg Mn)	constant	3.13	3.12	2.95	2.42	2.65	2.53	2.38	2.18	1.81	1.72
Nickel	current	1711	1761	1742	1742	1735	1739	1936	2075	2363	2846
(metric ton)	constant	6155	6427	6335	6177	6109	5797	6368	7281	8205	8978
Steel	current	108.2	109.5	109.5	109.5	107.3	109.3	102.0	94.5	100.5	124.9
(metric ton)	constant	389.2	399.6	398.2	388.3	377.8	364.3	335.5	331.6	349.0	394.0
Phosphate Rock	current	13.0	11.5	11.5	12.5	14.0	13.0	12.0	11.5	11.3	11.0
(metric ton)	constant	46.8	42.0	41.8	44.3	49.3	43.3	39.5	40.4	39.2	34.7

Table 1.3

1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
91	99	124	178	118	109	120	92	92	117	95	74	80	76
58	58	62	57	48	89	139	88	82	67	58	61	64	71
112	109	187	216	148	119	101	103	97	107	119	88	98	92
108	96	165	152	89	93	107	96	99	84	84	69	85	96
126	167	179	381	240	147	105	92	103	223	151	91	96	66
104	98	130	116	89	110	103	95	102	108	98	88	102	97
80	72	105	101	67	88	92	79	125	139	109	111	107	118
127	115	140	152	115	110	105	91	105	108	102	95	98	91

1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0.54 1.56	0.64 1.72	1.13 2.51	1.56 2.78	1.25 1.94	2.05 3.13	3.79 5.38	3.40 4.10	3.29 3.58	2.60 2.60	2.08 2.17	1.74 1.84	2.12 2.32	2.40 X
0.99 2.87	1.12 2.98	1.53 3.39	1.62 2.87	1.85 2.89	3.30 5.05	6.79 9.62	3.20 3.85	3.89 4.21	4.58 4.58	3.87 4.04	3.17 3.37	3.15 3.45	3.30 X
1.05 3.06	1.05 2.97	1.06 2.35	1.40 2.49	1.39 2.16	1.54 2.35	2.69 3.81	2.19 2.64	2.16 2.34	2.23 2.23	2.02 2.11	1.93 2.05	2.33 2.55	3.46 X
129.0 375.0	147.0 389.9	350.0 777.8	542.0 961.0	363.1 566.5	254.5 389.7	272.2 385.6	367.5 442.8	334.2 359.0	433.9 433.9	482.8 504.0	292.9 311.3	276.9 303.3	252.1 X
55.7 161.9	56.0 148.5	93.0 206.7	121.0 214.5	111.9 174.6	105.2 161.1	88.4 125.2	93.8 113.0	108.1 117.3	128.9 128.9	126.4 131.9	108.5 115.3	128.8 141.1	118.2 X
58.4 169.8	56.0 148.5	98.0 217.8	132.0 234.0	119.6 186.6	112.4 172.1	95.3 135.0	100.7 121.3	[illegible] 125.1	125.3 125.3	130.8 136.5	109.3 116.2	136.0 149.0	135.9 X
62.1 180.5	69.1 183.3	136.8 304.0	178.0 315.6	138.4 215.9	122.7 187.9	95.5 135.3	124.9 150.5	156.3 169.3	168.3 168.3	154.6 161.4	132.6 140.9	137.3 150.4	140.2 X
0.10 0.29	0.16 0.43	0.21 0.46	0.65 1.16	0.45 0.70	0.25 0.39	0.18 0.25	0.17 0.21	0.21 0.23	0.63 0.63	0.37 0.39	0.19 0.20	0.19 0.20	0.11 X
1.35 3.91	1.48 3.93	2.01 4.47	1.58 2.81	1.33 2.07	1.58 2.42	1.51 2.13	2.14 2.58	2.88 3.08	2.76 2.76	2.48 2.58	2.39 2.54	2.44 2.67	2.27 X
0.14 0.41	0.16 0.43	0.17 0.37	0.18 0.33	0.25 0.39	0.26 0.39	0.28 0.39	0.29 0.35	0.33 0.35	0.38 0.38	0.40 0.42	0.37 0.40	0.43 0.47	0.37 X
370.5 1077.0	234.2 621.2	513.0 1140.0	998.0 1769.5	393.5 613.9	418.0 640.1	578.2 819.0	683.3 823.1	984.5 1066.6	673.8 673.8	569.9 594.9	464.4 493.5	729.9 799.5	1155.0 X
440.7 1281.1	425.9 1129.7	546.2 1213.8	1076.8 1909.2	857.0 1137.0	741.0 1134.8	852.3 1207.2	1079.2 1300.2	888.7 962.8	858.8 858.8	1043.0 1088.7	584.9 621.6	710.9 778.6	1017.0 X
261.1 759.0	217.3 576.4	377.5 838.9	669.0 1186.2	434.2 677.4	406.5 622.5	530.0 750.7	600.2 723.1	653.8 708.3	583.5 583.5	570.7 595.1	445.1 473.0	501.4 549.2	729.0 X
105 305	129 342	302 671	184 326	155 242	198 303	230 326	213 257	243 263	262 262	253 264	219 232	238 260	197 X
167 485	239 634	542 1204	372 660	245 382	376 576	454 643	410 494	395 428	504 504	468 489	353 375	453 496	373 X
0.74 2.15	0.79 2.10	1.36 3.01	1.42 2.51	1.16 1.81	1.69 2.59	1.55 2.20	1.57 1.89	1.69 1.83	2.05 2.05	1.85 1.93	1.60 1.70	1.85 2.03	1.79 X
286.0 831.4	299.0 793.1	289.0 642.2	353.0 625.9	371.0 578.8	295.6 452.7	320.9 454.5	398.4 523.7	387.4 419.7	313.6 313.6	275.0 287.1	285.8 303.7	302.2 331.0	530.8 X
1.37 3.99	2.40 6.37	5.14 11.41	3.67 6.51	2.74 4.28	3.41 5.22	3.58 5.07	3.75 4.52	4.43 4.80	4.60 4.60	2.48 4.46	3.93 4.17	3.64 3.99	3.67 X
0.37 1.07	0.37 0.99	0.78 1.73	0.77 1.37	0.67 1.04	0.87 1.33	0.91 1.29	1.05 1.27	1.29 1.39	1.54 1.54	1.17 1.22	0.91 0.96	1.15 1.25	1.02 X
38.0 110.5	37.6 99.7	65.6 145.8	78.6 139.4	59.3 92.5	79.6 121.9	89.8 127.2	91.8 110.6	160.2 173.6	192.9 192.9	144.6 150.9	145.2 154.3	135.2 148.1	151.0 X
17.35 50.43	19.16 50.82	20.90 46.44	44.52 78.94	54.27 84.67	53.56 82.02	54.26 76.86	55.74 67.16	56.50 61.21	55.70 55.70	58.05 60.63	56.40 59.94	57.47 62.95	57.77 X
1.7 4.9	1.9 5.0	2.7 6.0	11.2 19.9	10.9 17.0	11.7 17.9	12.8 18.1	12.9 15.5	18.6 20.2	30.5 30.5	34.4 35.9	33.2 35.3	29.1 31.9	28.5 X
25.1 73.0	30.4 80.6	87.8 195.1	131.1 232.4	120.3 187.7	137.9 211.2	131.6 186.4	160.0 192.8	335.0 362.9	358.0 358.0	354.1 369.6	323.6 343.9	283.9 311.0	259.1 X
639 1858	582 1544	551 1224	752 1333	877 1368	978 1498	1132 1603	1170 1410	1310 1419	1534 1534	1676 1749	1676 1781	1712 1875	1786 X
12.0 34.9	12.0 31.8	12.5 27.8	23.2 41.1	25.3 39.5	27.2 41.7	30.8 43.6	34.2 41.3	36.6 39.6	41.2 41.2	40.0 41.8	36.0 38.3	34.7 38.0	33.2 X
1080 3140	1071 2841	1786 3969	2059 3650	1237 1930	1401 2145	1309 1854	1365 1645	1985 2151	2183 2183	1742 1818	1480 1573	1592 1744	1379 X
254 738	302 801	430 956	593 1051	417 651	445 681	618 875	662 798	1208 1309	906 906	727 759	546 580	425 466	444 X
3501 10177	3770 10000	4828 10729	8201 14541	6870 10718	7582 11611	10762 15244	12908 15552	15458 16748	16775 16775	14159 14780	12826 13630	12988 14226	12273 X
309 898	377 1000	851 1891	1239 2197	743 1159	712 1090	591 837	593 714	742 804	761 761	846 883	745 792	764 837	922 X
10.5 30.5	10.8 28.7	10.1 22.4	12.8 22.7	19.3 30.1	16.1 24.7	13.4 19.0	15.9 19.2	14.3 15.5	17.6 17.6	18.5 19.3	19.3 20.5	21.6 23.7	17.1 X
0.63 1.83	0.64 1.68	0.75 1.66	1.12 1.99	1.38 2.15	1.45 2.22	1.48 2.10	1.43 1.72	1.38 1.49	1.57 1.57	1.68 1.75	1.64 1.74	1.52 1.66	1.43 X
2932 8523	3080 8170	3373 7496	3825 6782	4570 7129	4973 7615	5203 7370	4609 5553	5986 6485	7528 7528	7560 7891	7055 7497	7055 7727	7055 X
137.1 398.6	157.4 417.5	207.9 462.0	250.0 443.3	300.8 469.3	329.5 504.6	320.0 453.3	391.8 472.1	428.3 464.0	466.0 466.0	375.5 392.0	402.4 427.6	331.8 363.4	353.2 X
11.3 32.9	11.5 30.5	13.8 30.7	54.5 96.6	67.0 104.5	36.0 55.1	30.5 43.2	29.0 34.9	33.0 35.8	46.7 46.7	49.5 51.7	42.4 45.1	36.9 40.4	38.3 X

Source: The World Bank. X = not available. For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 1.1 Gross National Product, 1960–83

Sources: GNP: The World Bank, *The World Bank Atlas 1985*, (The World Bank, Washington, 1985). GNP growth rates: unpublished World Bank data. Gross Domestic Product data: The World Bank, *World Development Report* 1985 (Oxford University Press, New York, 1985), pp. 178–179.

Gross National Product is the sum of two components: the Gross Domestic Product, the final output of goods and services produced by the domestic economy (including net exports of goods and non-factor services), and net factor income from abroad. Net factor income from abroad is income residents receive on a net basis from abroad for factor services (labor, investment, and interest). Gross Domestic Product was estimated by the production method. This method sums the final outputs of the various sectors of the economy (agriculture, manufacturing, government services, etc.) from which the value of the inputs to production have been subtracted.

Gross national product in domestic currency was converted to U.S. dollars using a three-year average exchange rate, adjusted for domestic and U.S. inflation.

The average annual percentage change of GNP was calculated by fitting a least square regression line to the logarithmic values for GNP.

The agricultural sector includes forestry, hunting, and fishing; the industrial sector includes mining, manufacturing, construction, electricity, water, and gas; and the service sector summarizes all other economic activity. Because a sizeable fraction of agricultural, forestry, hunting, and fishing output does not enter the money economy (especially in developing countries with large subsistence populations), the output of the agricultural sector and of GDP are often difficult to estimate.

The Gross National Product data are produced by countries that use a market-oriented system of national accounts. Over the years, World Bank economists have reviewed the national income accounting practices of developing countries and adjusted their national GNP figures to fit common definitions. The Economic Analysis and Projection Department of the Bank reviews country data annually and futher adjusts them as needed.

For additional information on procedures used to estimate GNP, see the Technical Notes, World Development Indicators Annex, *World Development Report*.

Table 1.2 Labor Force, 1965–2000

Sources: Total labor force data: U.N. Food and Agriculture Organization (FAO), *FAO Production Yearbook 1983* (U.N. Food and Agriculture Organization, Rome, 1984), pp. 61–72. Labor force by economic sector and labor force growth rates: The World Bank, *World Development Report 1985* (Oxford University Press, New York, 1985), pp. 214–215.

The labor force is made up of all persons who work to produce economic goods and services. It includes all employed persons (employers, persons working on their own account, salaried employees, wage earners, unpaid family workers, members of producer cooperatives and armed forces) and all the unemployed, both experienced workers and those looking for work for the first time.

The labor force sectors correspond to the production sectors used in Table 1.1.

Most of the data were originally compiled by the International Labor Organization (ILO) from national censuses and labor surveys. The ILO standardizes labor force data to a base year (1970) and prepares estimates and projections of the size and sectoral composition of the labor force for the years 1980, 1990, and 2000. The ILO estimated the size of the 1970 labor force using data collected from population censuses and labor force and demographic surveys. Data for each country were adjusted to fit the ILO definition of economically active. The most difficult groups to estimate were the unpaid household workers (mostly female) and young people working on family farms.

When data for 1970 were unavailable, estimates were made based on experiences in culturally and socially similar countries. For example, the ILO estimated missing data for Jordan, Saudi Arabia, Yemen, and Democratic Yemen by analyzing recent results of censuses from ten other Islamic countries.

For a complete discussion of definitions and methods, see *Labor Force Estimates and Projections 1950–2000*, (International Labor Organization, Geneva, 1977). Data for the 1980 base year will be published in early 1986.

Table 1.3 World Commodity Prices and Indexes, 1961–84

Sources: The World Bank, *Commodity Trade and Price Trends* (The Johns Hopkins University Press, Baltimore, Maryland, 1985), and unpublished World Bank data.

Price data are compiled from major marketplaces for standard grades of each commodity. For example, the gasoline series refers to 91/92 octane regular gasoline, in barges, fob (free on board) Rotterdam.

Average monthly current prices in local currencies were converted to U.S. dollars using the monthly average exchange rate. The monthly average U.S. dollar figures were averaged to produce an annual average dollar figure. The resulting U.S. dollar series was adjusted to 1980 constant dollars using the Manufacturing Unit Value (MUV) Index. The MUV Index is a composite price index of all manufactured goods traded internationally.

The aggregate price indexes have the following components:

1. All Foods: beverages, cereals, fats and oils, other foods;
2. Beverages: coffee, cocoa, tea;
3. Cereals: maize, rice, wheat, grain sorghum;
4. Fats and Oils: palm oil, coconut oil, groundnut oil, soybeans, copra, groundnut meal, soybean meal;
5. Other Foods: sugar, beef, bananas, oranges;
6. Non-food Agriculturals: cotton, jute, rubber, tobacco;
7. Timber: logs;
8. Metals and Minerals: copper, tin, nickel, bauxite, aluminum, iron ore, manganese ore, lead, zinc, phosphate rock.

2. Population and Health

The tables in this chapter deal with the size and growth of population and include a few important indicators of the state of health and education. Tables 2.1 and 2.2 present national, regional, and global data on population size and growth and on two major factors that determine population change—birth and death rates. These statistics and those on age distribution (Table 2.3) and infant mortality (Table 2.4) are taken from periodic assessments by the Population Division of the U.N. Department of International Economic and Social Affairs.

Of the 146 countries shown in these tables, 128 conducted a national population census or major population survey between 1970 and 1982; 14 conducted a census before 1970; 3 (Somalia, Oman, and Lao PDR) have not conducted a modern census, and 1 country, Ethiopia, conducted its first census in 1984. Although the number and frequency of national censuses have increased over the past decade, their quality is sometimes poor. In many African countries they are inadequate and the U.N. Population Division must substantially adjust the figures. Censuses are generally good in Latin America. In Asia, the results from recent censuses in India and China—the world's two most populous countries—could not be fully incorporated into the U.N.'s 1982 assessment.

Crude birth and death rates along with net migration are the three basic determinants of population change in a country. When birth rates remain relatively high and death rates decline, the population increases rapidly, as many developing countries have experienced in the past 20 years. When both birth and death rates decline, the population growth rate also declines. In Australia, Canada, the United States, and some of the oil-rich Middle East countries, immigration has considerably increased the population. In other countries—Afghanistan, Ethiopia, Lebanon, and Viet Nam, for example—emigration has had the opposite effect.

Crude birth and death rates are heavily influenced by the age structures of the population, as shown in Table 2.3. In Kenya, Botswana, Rwanda, and many other African countries, more than 45 percent of the population is under 15 years of age and only 1 or 2 percent is over 65 years. The reverse is true in Europe: in Sweden, Switzerland, Denmark, and Norway, at least 15 percent of the population is over 65 years of age and about the same percent is under 15 years. Age distribution also has important implications for economic development (essentially, the middle group must support the other two groups by providing services such as education, jobs, social welfare, and health care).

In addition to crude birth and death rates, Table 2.2 gives figures for two synthetic indicators used to analyze population and health trends. The "total fertility rate" is an estimate of the number of children an average woman would have if current age-specific fertility rates remain constant during her reproductive years. Total fertility rates have fallen worldwide from 4.9 in 1960–65 to 3.55 in 1980–85. Currently, the highest rates are for women in Kenya (8.1), Jordan (7.4), Rwanda (7.3), and Libya (7.2); they are lowest in Switzerland (1.3), the Federal Republic of Germany (1.4), Luxembourg (1.4), and the Netherlands (1.4).

"Life expectancy at birth" is a common measure of mortality. Many developing countries have achieved impressive gains in life expectancy at birth largely because infant and childhood mortality have been reduced. In Africa, infant mortality declined 27 percent between 1960–65 and 1980–85, in Asia by 35 percent, and in South America by 37 percent. But in many countries one of ten babies still dies in the first year of life.

Food supplies are inadequate in many countries, as Table 2.4 shows. India, for example, is able to supply only about 90 percent of the calories needed to feed its population. Yet in other countries—Libya, Ireland, and Bulgaria, for example—calorie supplies, as estimated by the U.N. Food and Agriculture Organization, are in substantial excess of requirements. The "minimum daily calorie requirement" is the energy intake that is adequate to meet the needs of an average healthy person. It is important to note, however, that the figures are national averages and therefore do not reflect sharp differences in access to food between the rich and the poor in a country. Nor do they reflect the amounts of dietary energy lost or wasted during storage, preparation, and cooking of food.

The growing use of contraception, also shown in Table 2.4, indicates that many families desire to control the number and spacing of children. It also indicates the growing demand by women for preventive health care.

Most countries attempt to provide basic education to all children. An important indicator of their success in achieving this social goal is the percentage of school-age children who actually attend school, as shown in Table 2.5.

Table 2.1 ESTIMATED SIZE AND GROWTH OF POPULATION,

	Estimated Population (thousands)			Estimated Average Annual Growth of Population (percent)			
	1960	1985	2000	1960–65	1970–75	1980–85	2000–05
WORLD	**3013816**	**4842048**	**6127117**	**1.96**	**2.03**	**1.67**	**1.39**
AFRICA	**277541**	**553210**	**877439**	**2.44**	**2.74**	**3.01**	**2.96**
Algeria	10800	21993	35194	1.98	3.06	3.28	2.50
Angola	4816	8754	13234	1.45	3.08	2.51	2.81
Benin	2251	4005	6381	1.64	2.33	2.86	3.10
Botswana	481	1079	1865	2.63	3.77	3.46	3.65
Burkina Faso	4279	6939	10542	1.65	1.85	2.34	2.82
Burundi	2927	4631	6951	1.87	1.62	2.67	2.51
Cameroon	5545	9714	14424	1.95	2.24	2.54	2.62
Cape Verde	195	321	382	2.80	1.97	1.36	0.91
Central African Rep	1605	2567	3736	1.48	1.85	2.29	2.58
Chad	3064	5018	7304	1.69	1.97	2.28	2.57
Comoros	215	457	715	2.25	3.40	3.04	2.36
Congo	972	1740	2646	2.06	2.37	2.59	2.84
Djibouti	78	293	X	X	5.60	2.00	X
Egypt	25490	46800	65200	2.50	1.95	2.52	1.89
Equatorial Guinea	252	392	559	1.33	1.78	2.15	2.40
Ethiopia	20021	36454	58407	2.32	2.65	2.60	3.02
Gabon	867	1166	1611	0.87	1.08	1.64	2.74
Gambia	374	643	898	2.28	2.23	1.94	2.32
Ghana	6772	13478	21923	2.79	2.58	3.25	2.93
Guinea	3271	5429	7935	1.68	2.01	2.33	2.56
Guinea-Bissau	540	889	1241	0.56	3.55	1.91	2.32
Ivory Coast	3731	9797	15581	3.80	3.95	3.44	2.92
Kenya	7903	20600	38534	3.48	3.87	4.12	3.89
Lesotho	871	1520	2251	2.01	2.18	2.53	2.61
Liberia	1047	2191	3564	2.58	2.94	3.16	3.18
Libya	1349	3604	6072	3.70	4.03	3.84	3.00
Madagascar	5362	10012	15552	2.18	2.48	2.80	2.93
Malawi	3529	7016	11669	2.38	2.69	3.23	3.33
Mali	4636	8053	12363	1.93	2.03	2.78	2.74
Mauritania	981	1888	2999	2.35	2.61	2.93	3.01
Mauritius	660	1050	1298	3.18	0.47	1.90	1.09
Morocco	11626	23602	36325	2.73	2.45	3.26	2.40
Mozambique	6546	14085	21779	2.08	3.55	3.05	2.87
Niger	3234	6115	9750	2.89	2.36	2.82	3.15
Nigeria	42305	95198	61930	2.80	3.35	3.34	3.49
Rwanda	2753	6115	10565	2.96	3.19	3.46	3.58
Senegal	3041	6520	10036	2.64	3.48	2.66	2.92
Sierra Leone	2475	3602	4868	1.33	1.43	1.77	2.12
Somalia	2271	5552	7079	1.98	2.27	3.71	2.76
South Africa	18281	32392	46918	2.12	2.27	2.48	2.28
Sudan	11165	21550	32926	2.03	2.89	2.86	2.54
Swaziland	338	649	1041	2.31	2.52	3.03	3.05
Tanzania, United Rep	10026	22499	39129	2.89	3.25	3.52	3.62
Togo	1514	2923	4599	1.44	2.17	2.86	3.03
Tunisia	4221	7209	9725	1.85	1.81	2.41	1.56
Uganda	6562	15697	26774	4.08	2.68	3.50	3.36
Zaire	17755	33052	52410	1.90	2.65	2.94	3.10
Zambia	3141	6666	11237	2.80	2.89	3.31	3.49
Zimbabwe	3604	8767	15132	4.13	3.17	3.50	3.59
NORTH AMERICA	**268584**	**400802**	**488073**	**1.85**	**1.57**	**1.38**	**1.13**
Barbados	231	265	307	0.39	0.39	0.82	0.90
Canada	17909	25605	29435	1.85	1.20	1.21	0.69
Costa Rica	1236	2600	3596	3.63	2.52	2.64	1.72
Cuba	7029	10038	11718	2.10	1.70	0.62	0.76
Dominican Rep	3224	6243	8407	2.91	2.85	2.32	1.74
El Salvador	2574	5552	8708	3.09	2.91	2.93	2.62
Guatemala	3966	8403	12739	3.03	3.07	2.92	2.44
Haiti	3723	6585	9860	2.11	2.26	2.51	2.70
Honduras	1943	4372	6978	3.41	3.18	3.39	3.08
Jamaica	1629	2323	2849	1.55	1.78	1.36	1.13
Mexico	37073	78996	109180	3.20	3.23	2.59	1.70
Nicaragua	1493	3272	5261	3.19	3.20	3.32	2.72
Panama	1148	2180	2893	2.89	2.65	2.17	1.48
Trinidad and Tobago	843	1118	1321	2.90	1.04	0.92	1.00
United States	180671	237660	268079	1.46	1.04	0.86	0.68
SOUTH AMERICA	**146874**	**268825**	**359581**	**2.75**	**2.33**	**2.24**	**1.63**
Argentina	20616	30564	37197	1.55	1.67	1.58	1.13
Bolivia	3428	6371	9724	2.27	2.48	2.69	2.82
Brazil	72594	135564	179487	2.99	2.39	2.23	1.51
Chile	7585	12074	14934	2.30	1.70	1.68	1.15
Colombia	15538	28714	37999	3.07	2.16	2.15	1.50
Ecuador	4422	9380	14596	2.99	2.91	3.13	2.57
Guyana	569	953	1196	2.52	1.89	1.95	1.21
Paraguay	1778	3681	5405	2.54	3.19	3.00	2.16
Peru	9931	19698	27952	2.88	2.78	2.60	1.91
Suriname	290	353	423	2.72	-0.29	0.06	1.58
Uruguay	2538	3012	3364	1.19	0.14	0.70	0.65
Venezuela	7550	18386	27207	3.88	3.58	3.26	2.14

1960–2005 Table 2.1

	Estimated Population (thousands)			Estimated Average Annual Growth of Population (percent)			
	1960	1985	2000	1960–65	1970–75	1980–85	2000–05
ASIA	**1665573**	**2824008**	**3543693**	**2.14**	**2.35**	**1.73**	**1.22**
Afghanistan	10016	14636	24180	2.08	2.39	0.04	1.95
Bahrain	156	431	688	4.04	4.28	4.32	2.19
Bangladesh	51585	101147	145800	2.47	2.77	2.74	2.04
Bhutan	867	1417	1893	1.81	2.05	2.03	1.71
Burma	21780	39487	55186	2.28	2.40	2.52	1.94
China	667322	1063105	1255656	1.76	2.37	1.17	0.95
Cyprus	573	667	759	0.32	-0.19	1.15	0.77
India	431463	761175	961531	2.50	2.31	1.99	1.09
Indonesia	96194	164887	204486	2.14	2.41	1.76	1.15
Iran	20301	45106	65549	3.41	3.21	3.02	1.97
Iraq	6847	15676	24926	3.05	3.27	3.43	2.71
Israel	2114	4298	5376	3.85	3.00	2.05	1.22
Japan	94096	120072	127683	0.99	1.33	0.57	0.29
Jordan	1695	3509	6400	2.93	2.46	3.66	3.70
Kampuchea, Dem	5433	7393	9918	2.45	0.46	2.89	0.89
Korea, Dem People's Rep	10526	20082	27256	2.79	2.64	2.31	1.62
Korea, Rep	25003	40872	49485	2.64	2.00	1.39	0.88
Kuwait	278	1785	2969	10.53	6.04	5.26	2.43
Lao People's Dem Rep	2355	4423	6213	2.37	2.54	2.51	1.93
Lebanon	1857	2668	3617	2.94	2.28	-0.01	1.67
Malaysia	8205	15551	20615	3.00	2.50	2.29	1.35
Mongolia	931	1900	2673	2.78	2.93	2.66	1.85
Nepal	9404	16482	23048	1.90	2.47	2.33	1.94
Oman	505	1228	1909	2.46	3.16	4.55	2.69
Pakistan	50093	101696	142554	2.66	2.69	3.08	2.02
Philippines	27904	54709	74810	3.04	2.51	2.49	1.53
Qatar	45	301	469	8.84	8.60	4.02	2.52
Saudi Arabia	4075	11240	18864	3.25	4.66	3.94	2.92
Singapore	1634	2572	2976	2.81	1.74	1.27	0.54
Sri Lanka	9889	16404	20843	2.43	1.67	2.03	1.20
Syrian Arab Rep	4561	10581	18102	3.10	3.46	3.69	2.82
Thailand	26867	51571	66115	3.02	2.58	2.09	1.44
Turkey	27509	49974	68466	2.49	2.50	2.33	1.67
United Arab Emirates	90	1312	1916	9.38	16.35	5.83	1.66
Viet Nam	33923	59451	78129	2.19	2.35	2.02	1.51
Yemen	4039	6547	9859	2.13	1.77	2.37	2.57
Yemen, Dem	1208	2124	3309	2.24	2.00	2.68	2.66
EUROPE	**425129**	**492009**	**513110**	**0.91**	**0.64**	**0.33**	**0.18**
Albania	1611	3050	4102	2.99	2.51	2.21	1.59
Austria	7048	7487	7498	0.58	0.20	-0.05	-0.08
Belgium	9153	9880	9925	0.67	0.33	0.04	-0.02
Bulgaria	7867	9220	9713	0.83	0.48	0.47	0.26
Czechoslovakia	13654	15648	16776	0.73	0.60	0.43	0.53
Denmark	4581	5144	5126	0.76	0.52	0.08	-0.18
Finland	4430	4875	4970	0.60	0.45	0.37	-0.02
France	45684	54608	57083	1.30	0.79	0.30	0.16
German Dem Rep	17240	16642	16553	-0.26	-0.26	-0.11	-0.03
Germany, Fed Rep	55433	61106	59755	1.25	0.37	-0.18	-0.33
Greece	8327	9932	10734	0.53	0.57	0.59	0.41
Hungary	9984	10797	10908	0.33	0.36	0.16	0.10
Ireland	2834	3595	4247	0.29	1.64	1.11	1.04
Italy	50223	56874	58155	0.67	0.83	0.25	0.00
Luxembourg	314	363	358	1.11	1.32	-0.12	-0.19
Malta	329	382	419	-0.55	1.19	0.68	0.53
Netherlands	11480	14506	15011	1.37	1.14	0.40	0.02
Norway	3581	4150	4227	0.78	0.66	0.27	0.03
Poland	29561	37556	41391	1.27	0.82	0.95	0.53
Portugal	8826	10077	10995	0.91	1.77	0.68	0.42
Romania	18407	23065	25629	0.67	0.85	0.76	0.60
Spain	30303	39019	43442	1.03	1.05	0.82	0.59
Sweden	7480	8278	8065	0.67	0.37	0.01	-0.20
Switzerland	5362	6289	5889	1.77	0.44	-0.26	-0.56
United Kingdom	52559	55640	56235	0.73	0.20	-0.01	0.01
Yugoslavia	18402	23191	25200	1.09	0.94	0.76	0.37
USSR	**214335**	**278373**	**314818**	**1.49**	**0.95**	**0.95**	**0.69**
OCEANIA	**15762**	**24820**	**30403**	**2.08**	**1.85**	**1.50**	**1.19**
Australia	10315	15714	18668	1.98	1.64	1.31	1.03
Fiji	394	684	821	3.27	2.03	1.66	0.79
New Zealand	2372	3291	3693	2.05	1.81	0.75	0.63
Papua New Guinea	1920	3696	5292	2.24	2.62	2.69	2.05
Solomon Islands	126	273	X	2.50	3.40	3.60	X
ANTARCTICA							

Source: U.N. Department of International Economic and Social Affairs
X = not available
For additional information, see Sources and Technical Notes

Table 2.2 BIRTH, DEATHS, FERTILITY, AND MORTALITY, 1950–85

	Estimated Crude Birth Rate (births per thousand population)		Estimated Crude Death Rate (deaths per thousand population)		Estimated Total Fertility Rate		Estimated Life Expectancy at Birth	
	1960–65	1980–85	1960–65	1980–85	1960–65	1980–85	1980–1985 average	Years Added Since 1950–1955
WORLD	**35.9**	**27.3**	**16.4**	**10.6**	**4.92**	**3.55**	**64.6**	**14.7**
AFRICA	**48.3**	**46.4**	**23.3**	**16.5**	**6.54**	**6.43**	**49.7**	**12.2**
Algeria	50.4	45.1	19.4	12.3	7.38	6.97	57.8	14.7
Angola	49.4	47.3	30.2	22.2	6.38	6.39	42.0	12.0
Benin	48.3	51.0	31.9	22.5	6.81	7.00	42.5	10.0
Botswana	52.6	50.0	19.6	12.7	6.42	6.50	54.5	12.0
Burkina Faso	50.2	47.8	30.3	22.2	6.50	6.50	42.0	12.0
Burundi	45.6	47.6	25.3	20.9	5.69	6.44	44.0	7.5
Cameroon	43.2	43.2	23.7	17.8	5.77	5.79	48.0	12.0
Cape Verde	44.8	23.9	16.9	10.3	6.09	2.64	57.0	13.5
Central African Rep	43.5	44.7	28.6	21.8	5.66	5.89	43.0	10.5
Chad	45.5	44.2	28.6	21.4	6.00	5.89	43.0	10.5
Comoros	48.2	46.3	21.2	15.9	6.32	6.29	50.0	10.0
Congo	45.2	44.5	24.7	18.6	5.87	5.99	46.5	10.5
Djibouti	X	47.0	X	20.5	X	X	X	X
Egypt	45.9	38.4	19.8	12.5	6.56	5.23	57.3	16.6
Equatorial Guinea	41.3	42.5	28.0	21.0	5.53	5.66	44.0	10.5
Ethiopia	50.2	49.2	27.0	21.5	6.66	6.70	42.9	10.0
Gabon	31.5	34.6	22.8	18.1	4.06	4.67	49.0	11.0
Gambia	47.2	48.4	33.0	29.0	6.36	6.39	35.0	4.4
Ghana	48.2	47.0	20.4	14.6	6.48	6.50	52.0	12.0
Guinea	48.2	46.8	31.4	23.5	6.39	6.19	40.2	9.5
Guinea-Bissau	41.4	40.7	27.4	21.7	5.06	5.38	43.0	9.5
Ivory Coast	43.2	46.0	24.7	18.0	6.61	6.70	47.0	11.0
Kenya	57.1	55.1	22.5	14.0	8.15	8.12	52.9	14.3
Lesotho	42.8	41.7	22.7	16.4	5.75	5.79	49.3	12.0
Liberia	45.8	48.7	22.9	17.2	6.27	6.90	49.0	11.5
Libya	49.0	45.6	18.3	10.9	7.17	7.17	57.9	15.0
Madagascar	43.8	44.4	22.0	16.5	5.79	6.09	49.6	11.9
Malawi	53.6	52.1	27.5	19.9	6.87	7.00	45.0	11.0
Mali	50.9	50.2	28.6	22.4	6.52	6.70	42.0	9.5
Mauritania	50.2	50.1	26.7	20.9	6.86	6.90	44.0	10.5
Mauritius	42.5	25.5	9.1	6.0	5.73	2.76	66.7	15.7
Morocco	50.1	44.0	19.6	11.5	7.15	6.44	57.9	15.0
Mozambique	44.8	44.1	22.6	16.5	5.70	6.09	49.4	12.0
Niger	45.8	51.0	29.5	22.9	7.06	7.10	42.5	9.5
Nigeria	51.6	50.4	23.6	17.1	6.87	7.10	48.5	12.0
Rwanda	51.2	51.1	21.6	16.6	6.83	7.30	49.5	9.5
Senegal	47.2	47.7	26.2	21.2	6.43	6.50	43.3	8.6
Sierra Leone	48.0	47.4	34.7	29.7	6.11	6.13	34.0	5.0
Somalia	46.5	46.5	26.7	21.3	6.11	6.09	42.9	10.0
South Africa	41.4	38.7	20.3	13.9	5.62	5.07	53.5	12.0
Sudan	47.0	45.9	24.8	17.4	6.68	6.58	47.7	10.5
Swaziland	48.3	47.5	24.4	17.2	6.41	6.50	48.6	12.9
Tanzania, United Rep	51.7	50.4	22.8	15.3	6.86	7.10	51.0	14.0
Togo	47.7	45.4	24.4	16.9	6.15	6.09	48.7	12.7
Tunisia	46.5	34.1	17.9	10.1	7.17	4.92	60.6	16.0
Uganda	48.7	49.9	20.1	14.7	6.91	6.90	52.0	12.0
Zaire	48.1	45.2	23.8	15.8	6.08	6.09	50.0	11.5
Zambia	49.4	48.1	21.4	15.1	6.62	6.76	51.3	13.5
Zimbabwe	46.7	47.2	18.0	12.3	6.61	6.60	55.7	14.2
NORTH AMERICA	**28.2**	**21.6**	**10.0**	**6.6**	**4.11**	**2.69**	**71.1**	**6.7**
Barbados	29.1	19.9	9.2	8.6	4.05	2.23	71.6	14.1
Canada	25.3	16.2	7.7	7.1	3.62	1.81	74.9	5.8
Costa Rica	45.3	30.5	9.1	4.2	6.95	3.50	73.0	15.7
Cuba	35.3	16.9	8.8	6.4	4.67	1.97	73.4	14.6
Dominican Rep	47.7	33.1	15.4	8.0	7.32	4.18	62.6	17.5
El Salvador	47.4	40.2	15.3	8.1	6.85	5.56	64.8	19.5
Guatemala	47.6	38.4	17.3	9.3	6.85	5.17	60.7	18.0
Haiti	44.4	41.3	21.6	14.2	6.15	5.74	52.7	15.1
Honduras	50.9	43.9	17.7	10.1	7.36	6.50	59.9	17.7
Jamaica	39.6	28.3	9.1	6.7	5.45	3.38	70.3	13.1
Mexico	44.9	33.9	11.3	7.1	6.74	4.61	65.7	15.0
Nicaragua	50.3	44.2	17.1	9.7	7.34	5.94	59.8	17.5
Panama	40.8	28.0	9.6	5.4	5.92	3.46	71.0	15.7
Trinidad and Tobago	36.3	24.6	7.3	6.2	5.02	2.90	70.1	12.2
United States	22.6	16.0	9.4	9.3	3.32	1.85	74.0	5.0
SOUTH AMERICA	**39.7**	**30.9**	**12.2**	**8.5**	**5.80**	**4.00**	**64.0**	**11.7**
Argentina	23.2	24.6	8.8	8.7	3.08	3.38	69.7	7.0
Bolivia	46.1	44.0	21.5	15.9	6.62	6.25	50.7	10.3
Brazil	42.1	30.6	12.3	8.4	6.15	3.81	63.4	12.4
Chile	35.7	24.8	11.9	7.7	5.02	2.90	67.0	12.9
Colombia	44.6	31.0	12.2	7.7	6.72	3.93	63.6	13.0
Ecuador	46.1	40.6	15.8	8.9	6.99	6.00	62.6	15.7
Guyana	40.4	28.5	8.6	5.9	6.01	3.26	68.2	13.0
Paraguay	42.2	36.0	11.9	7.2	6.62	4.85	65.1	13.2
Peru	46.3	36.7	17.6	10.7	6.87	5.00	58.6	14.7
Suriname	44.4	29.5	10.3	6.1	6.56	4.10	69.4	13.4
Uruguay	21.9	19.5	9.6	10.2	2.89	2.76	70.3	4.0
Venezuela	45.2	35.2	10.1	5.6	6.70	4.33	67.8	15.5

Table 2.2

	Estimated Crude Birth Rate (births per thousand population)		Estimated Crude Death Rate (deaths per thousand population)		Estimated Total Fertility Rate		Estimated Life Expectancy at Birth	
	1960–65	1980–85	1960–65	1980–85	1960–65	1980–85	1980–1985 average	Years Added Since 1950–1955
ASIA	**40.7**	**27.4**	**19.4**	**10.2**	**5.67**	**3.56**	**57.9**	**16.7**
Afghanistan	50.8	49.6	30.0	27.3	7.01	6.90	37.0	5.4
Bahrain	47.0	32.3	13.8	5.3	7.17	4.63	68.2	17.2
Bangladesh	46.7	44.8	22.0	17.5	6.68	6.15	47.8	7.4
Bhutan	42.2	38.4	24.1	18.1	5.92	5.53	45.9	9.6
Burma	42.8	37.9	19.9	12.7	5.84	5.33	55.0	15.0
China	37.2	18.5	19.7	6.8	5.38	2.33	67.4	26.8
Cyprus	25.2	19.7	10.5	8.2	3.42	2.31	74.3	7.3
India	47.1	33.2	22.2	13.3	6.51	4.41	52.5	13.8
Indonesia	42.9	30.7	21.5	13.0	5.42	3.89	52.5	15.0
Iran	51.8	40.5	17.7	10.4	8.13	5.64	60.2	14.1
Iraq	49.3	44.9	18.8	10.7	7.17	6.66	59.0	15.0
Israel	25.5	23.6	6.0	6.8	3.85	3.09	74.0	8.6
Japan	17.2	12.4	7.3	6.7	2.03	1.71	76.6	12.6
Jordan	48.0	44.9	18.7	8.4	7.17	7.38	64.2	21.0
Kampuchea, Dem	44.9	45.5	20.4	19.6	6.29	5.12	43.4	4.0
Korea, Dem People's Rep	39.5	30.5	12.2	7.4	5.57	4.00	64.6	17.1
Korea, Rep	39.6	21.0	12.5	6.3	5.37	2.46	67.5	20.0
Kuwait	44.5	36.8	9.0	3.5	7.38	6.15	71.2	15.4
Lao People's Dem Rep	42.2	40.6	18.5	15.5	5.68	5.84	49.7	9.3
Lebanon	42.7	29.3	13.3	8.8	6.35	3.79	65.0	9.0
Malaysia	43.2	29.2	13.3	6.4	6.69	3.69	66.9	18.4
Mongolia	41.2	33.8	13.4	7.2	5.72	4.82	64.6	19.6
Nepal	45.8	41.7	25.0	18.4	5.86	6.25	45.9	9.6
Oman	50.4	47.3	26.1	15.9	7.17	7.07	49.7	15.0
Pakistan	48.4	42.6	21.9	15.2	7.15	5.84	50.0	11.1
Philippines	43.6	32.3	13.1	6.9	6.57	4.20	64.5	17.0
Qatar	40.8	30.1	16.7	4.6	6.97	6.76	70.6	23.6
Saudi Arabia	48.9	43.0	21.3	12.1	7.26	7.07	56.0	17.0
Singapore	34.0	18.0	7.1	5.3	4.87	1.74	72.2	11.8
Sri Lanka	34.7	27.0	8.5	6.7	5.12	3.37	67.5	10.9
Syrian Arab Rep	47.4	46.5	16.6	7.2	7.46	7.17	67.0	21.0
Thailand	43.5	28.6	13.4	7.7	6.42	3.59	62.7	15.7
Turkey	41.0	32.5	15.0	9.0	6.01	4.45	63.0	16.0
United Arab Emirates	43.6	27.0	17.3	4.0	6.87	5.94	70.6	23.6
Viet Nam	41.1	31.2	19.5	10.1	5.64	4.30	58.8	18.4
Yemen	49.3	48.5	28.1	21.6	6.97	6.76	44.0	11.0
Yemen, Dem	50.3	47.6	27.9	18.8	6.97	6.87	46.5	13.5
EUROPE	**18.7**	**14.0**	**10.2**	**10.7**	**2.59**	**1.90**	**73.2**	**7.9**
Albania	39.9	27.7	10.1	5.8	5.74	3.60	70.9	15.7
Austria	18.5	12.1	12.5	12.6	2.79	1.63	73.0	7.3
Belgium	17.1	12.1	12.1	12.2	2.66	1.60	73.3	5.8
Bulgaria	16.9	15.4	8.2	10.7	2.19	2.25	72.3	8.2
Czechoslovakia	16.3	16.1	9.5	11.8	2.40	2.20	71.6	5.7
Denmark	17.0	11.1	9.7	10.9	2.59	1.52	74.9	3.9
Finland	18.1	12.7	9.3	10.3	2.58	1.60	73.2	6.9
France	18.0	13.8	11.2	10.7	2.85	1.83	74.5	8.0
German Dem Rep	17.4	12.5	13.3	13.7	2.45	1.65	72.7	5.6
Germany, Fed Rep	18.0	10.2	11.4	12.0	2.49	1.42	73.3	5.8
Greece	18.1	15.8	7.8	9.9	2.18	2.31	74.0	8.1
Hungary	13.6	14.3	10.1	12.7	1.83	2.06	71.2	7.2
Ireland	21.8	20.9	11.8	9.8	3.96	3.19	73.0	6.1
Italy	18.8	12.8	9.8	10.4	2.55	1.81	74.4	8.4
Luxembourg	16.0	10.1	11.9	11.9	2.36	1.38	72.8	6.9
Malta	22.6	17.3	8.8	10.5	3.11	1.97	71.7	5.8
Netherlands	20.9	11.6	7.8	8.7	3.14	1.44	75.9	3.8
Norway	17.4	12.3	9.5	10.5	2.90	1.69	75.9	3.2
Poland	20.1	18.5	7.6	9.0	2.66	2.25	72.0	10.7
Portugal	24.0	17.8	7.7	9.9	3.06	2.28	70.8	11.5
Romania	16.7	17.4	8.6	9.7	2.01	2.45	70.9	9.8
Spain	21.5	17.0	8.8	8.8	2.87	2.40	74.3	10.4
Sweden	14.5	10.5	10.0	11.6	2.34	1.55	75.8	4.0
Switzerland	18.5	8.0	9.5	10.7	2.52	1.33	75.9	6.7
United Kingdom	18.2	12.8	11.8	12.4	2.83	1.78	73.7	4.5
Yugoslavia	22.1	16.4	9.4	8.8	2.70	2.07	71.2	13.1
USSR	**22.3**	**18.8**	**7.2**	**9.3**	**2.54**	**2.36**	**70.9**	**9.2**
OCEANIA	**26.7**	**21.1**	**10.5**	**8.4**	**3.69**	**2.71**	**67.6**	**6.6**
Australia	21.9	16.2	8.7	7.7	3.28	2.00	74.4	4.8
Fiji	39.4	27.2	7.0	4.1	5.92	3.18	72.5	11.9
New Zealand	25.9	15.6	8.9	8.1	3.79	1.85	73.4	3.8
Papua New Guinea	43.7	40.4	21.3	13.6	6.25	5.99	53.3	18.2
Solomon Islands	X	47.0	X	11.0	X	X	X	X
ANTARCTICA								

Sources: U.N. Department of International Economic and Social Affairs.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 2.3 AGE DISTRIBUTION, 1960–2000

	Age Distribution (percent of total population)								
	0–14			15–64			65+		
	1960	1985	2000	1960	1985	2000	1960	1985	2000
WORLD	**37.5**	**33.7**	**30.4**	**57.5**	**60.6**	**63.0**	**5.1**	**5.7**	**6.6**
AFRICA	**43.4**	**45.4**	**45.2**	**53.4**	**51.5**	**51.6**	**3.2**	**3.0**	**3.0**
Algeria	43.8	45.9	43.2	52.4	50.6	53.5	3.9	3.5	3.3
Angola	41.8	44.6	45.2	55.4	52.4	51.8	2.8	3.0	3.0
Benin	40.7	46.5	47.5	52.0	50.7	49.9	7.2	2.8	2.6
Botswana	47.5	49.7	49.0	49.1	48.3	48.9	3.4	2.0	2.1
Burkina Faso	42.3	44.4	45.3	54.8	52.8	51.7	2.9	2.8	3.0
Burundi	40.4	44.3	44.4	56.6	52.4	52.3	3.0	3.3	3.3
Cameroon	40.3	42.9	42.9	56.5	53.2	53.3	3.1	3.9	3.7
Cape Verde	45.6	31.4	25.8	51.6	64.7	68.8	2.8	3.9	5.4
Central African Rep	38.5	42.5	43.4	57.3	53.7	53.0	4.1	3.8	3.6
Chad	39.6	42.3	43.2	56.7	54.1	53.2	3.7	3.6	3.5
Comoros	44.2	46.2	44.4	52.8	51.0	52.6	3.0	2.8	3.0
Congo	40.9	43.6	44.4	55.8	53.0	52.3	3.2	3.4	3.4
Djibouti	X	X	X	X	X	X	X	X	X
Egypt	40.6	39.4	35.9	55.1	56.2	59.4	4.3	4.4	4.7
Equatorial Guinea	37.5	41.4	42.2	57.6	54.4	53.8	4.9	4.2	3.9
Ethiopia	44.0	45.8	46.4	53.5	51.7	50.9	2.6	2.6	2.6
Gabon	32.4	35.5	40.6	61.7	58.5	53.8	5.9	6.1	5.6
Gambia	39.7	42.5	43.5	56.7	54.5	53.4	3.6	3.1	3.1
Ghana	44.6	46.5	46.0	53.0	50.6	51.1	2.5	2.8	2.9
Guinea	41.5	43.1	43.9	54.2	54.0	53.0	4.3	2.9	3.1
Guinea-Bissau	37.4	40.7	41.4	59.1	55.0	54.4	3.5	4.3	4.1
Ivory Coast	40.9	45.1	45.5	54.4	52.0	51.5	4.7	2.9	3.0
Kenya	49.7	52.5	51.9	47.7	45.7	46.3	2.6	1.8	1.8
Lesotho	40.5	42.3	42.2	55.6	54.1	54.1	4.0	3.6	3.7
Liberia	42.4	46.8	47.0	54.4	50.2	50.1	3.2	3.0	2.9
Libya	43.3	46.5	44.7	52.7	51.2	52.5	4.0	2.3	2.8
Madagascar	41.1	44.2	44.8	55.9	52.4	51.8	3.0	3.4	3.4
Malawi	45.7	48.1	48.7	51.7	49.6	49.0	2.6	2.4	2.4
Mali	43.4	46.1	45.7	54.0	51.2	51.5	2.6	2.7	2.8
Mauritania	43.6	46.4	46.9	53.7	50.8	50.3	2.7	2.8	2.7
Mauritius	46.6	31.6	26.2	50.9	64.9	68.4	2.5	3.5	5.3
Morocco	44.8	45.6	40.7	52.6	51.4	55.9	2.6	3.0	3.4
Mozambique	40.8	44.8	44.4	56.2	51.8	52.2	3.0	3.4	3.4
Niger	41.5	46.7	47.7	52.8	50.0	49.8	5.7	3.3	2.5
Nigeria	45.4	48.3	48.9	52.3	49.3	48.6	2.3	2.4	2.4
Rwanda	44.6	48.8	49.5	53.0	48.8	48.0	2.5	2.5	2.5
Senegal	42.6	45.0	45.6	54.4	52.1	51.4	3.0	2.9	2.9
Sierra Leone	40.2	41.4	42.1	56.6	55.6	54.7	3.2	3.0	3.2
Somalia	41.5	43.7	44.8	55.4	52.3	51.4	3.0	4.0	3.8
South Africa	40.1	41.0	40.0	55.0	54.9	55.9	4.9	4.0	4.1
Sudan	44.3	45.1	43.5	52.7	52.1	53.5	2.9	2.8	3.1
Swaziland	43.2	46.0	46.2	53.9	51.0	50.8	2.8	3.0	3.0
Tanzania, United Rep	46.0	48.8	49.4	51.2	48.9	48.3	2.9	2.3	2.4
Togo	42.4	44.5	45.3	54.0	52.3	51.6	3.6	3.2	3.1
Tunisia	43.4	39.6	33.0	52.5	56.1	62.1	4.2	4.3	4.9
Uganda	46.6	48.5	48.2	50.8	49.0	49.2	2.6	2.5	2.5
Zaire	44.1	45.1	45.3	52.8	52.0	51.7	3.1	2.9	3.0
Zambia	45.2	47.3	47.9	52.4	50.0	49.4	2.4	2.7	2.7
Zimbabwe	45.5	47.6	48.1	51.8	49.6	49.2	2.7	2.7	2.7
NORTH AMERICA	**34.6**	**28.3**	**26.7**	**57.8**	**62.9**	**64.4**	**7.7**	**8.8**	**8.9**
Barbados	36.1	27.6	24.7	55.2	63.0	66.9	6.7	9.3	8.3
Canada	33.5	22.5	20.5	59.0	67.9	67.8	7.5	9.6	11.8
Costa Rica	47.5	36.7	32.5	49.5	59.5	62.5	3.0	3.8	4.9
Cuba	34.4	26.4	24.1	60.8	65.7	66.9	4.8	7.9	8.9
Dominican Rep	46.8	40.7	33.6	48.9	56.3	62.3	4.3	3.0	4.1
El Salvador	45.1	44.6	40.7	52.0	52.0	55.5	2.9	3.4	3.8
Guatemala	46.2	43.1	39.5	51.1	53.9	56.7	2.7	3.0	3.8
Haiti	40.9	43.6	43.4	55.1	53.0	53.5	3.9	3.4	3.1
Honduras	45.6	46.9	42.3	52.2	50.2	54.4	2.1	2.9	3.3
Jamaica	41.7	36.8	29.9	54.0	57.4	64.5	4.3	5.9	5.6
Mexico	45.6	42.2	34.1	51.0	54.3	61.7	3.4	3.5	4.2
Nicaragua	48.0	46.7	42.7	49.7	50.7	54.2	2.3	2.5	3.1
Panama	43.5	37.5	31.5	52.5	58.0	63.1	4.0	4.5	5.4
Trinidad and Tobago	43.0	31.6	27.6	53.0	62.6	65.0	4.0	5.8	7.4
United States	31.0	21.9	21.7	59.7	66.7	66.6	9.2	11.5	11.7
SOUTH AMERICA	**41.8**	**36.7**	**32.7**	**54.7**	**58.6**	**61.8**	**3.5**	**4.7**	**5.5**
Argentina	30.8	31.0	28.5	63.7	60.5	61.9	5.5	8.5	9.6
Bolivia	42.9	43.8	43.5	54.0	53.0	53.2	3.2	3.2	3.2
Brazil	43.6	36.4	31.8	53.5	59.3	62.8	2.9	4.3	5.4
Chile	39.1	31.2	28.0	56.5	63.1	65.2	4.3	5.7	6.7
Colombia	46.3	37.2	32.7	50.6	59.1	62.8	3.1	3.8	4.5
Ecuador	44.4	44.2	41.3	52.0	52.4	55.2	3.6	3.4	3.5
Guyana	48.5	37.0	28.2	48.2	59.1	66.9	3.3	3.9	4.9
Paraguay	46.0	41.7	37.7	50.7	54.8	58.5	3.3	3.6	3.7
Peru	43.3	40.5	35.6	53.2	55.9	60.1	3.4	3.6	4.3
Suriname	47.6	42.6	36.3	48.3	53.0	59.1	4.1	4.5	4.6
Uruguay	27.9	26.9	25.0	64.0	62.4	62.9	8.1	10.7	12.2
Venezuela	46.2	41.0	35.7	51.3	56.0	60.5	2.5	2.9	3.8

Table 2.3

	Age Distribution (percent of total population) 0–14			15–64			65+		
	1960	1985	2000	1960	1985	2000	1960	1985	2000
ASIA	**40.4**	**35.0**	**29.2**	**55.8**	**60.6**	**65.1**	**3.7**	**4.4**	**5.7**
Afghanistan	42.9	43.3	43.1	54.6	54.2	54.4	2.6	2.4	2.5
Bahrain	43.1	33.3	29.9	54.2	64.7	67.8	2.7	2.0	2.3
Bangladesh	40.8	45.7	40.4	55.1	51.2	56.7	4.0	3.1	2.8
Bhutan	40.2	40.0	37.1	56.6	56.6	59.1	3.2	3.3	3.7
Burma	39.1	41.3	37.1	57.5	55.0	58.7	3.4	3.7	4.2
China	40.1	30.7	24.0	56.6	64.1	69.2	3.3	5.2	6.8
Cyprus	36.7	24.9	23.0	57.4	65.0	66.9	5.9	10.1	10.1
India	41.3	37.3	30.7	54.6	59.2	64.5	4.1	3.5	4.8
Indonesia	40.2	38.5	29.8	56.5	58.1	65.6	3.3	3.4	4.6
Iran	47.1	43.1	36.9	50.8	53.5	59.5	2.1	3.4	3.6
Iraq	46.1	46.4	41.9	51.4	50.9	55.0	2.4	2.7	3.1
Israel	36.1	32.8	27.2	59.1	59.0	64.3	4.9	8.2	8.4
Japan	30.2	21.5	17.5	64.1	68.6	67.6	5.7	9.9	14.9
Jordan	44.4	47.8	48.8	51.5	49.4	48.5	4.1	2.8	2.7
Kampuchea, Dem	42.5	32.6	36.8	54.8	64.7	59.6	2.7	2.6	3.6
Korea, Dem Peoples Rep	43.7	38.1	33.0	53.0	58.1	62.5	3.3	3.8	4.5
Korea, Rep	41.9	29.7	25.3	54.7	65.9	68.2	3.3	4.4	6.5
Kuwait	34.8	41.1	36.8	62.9	57.4	60.3	2.2	1.5	2.9
Lao Peoples Dem Rep	41.3	42.8	38.4	56.4	54.1	58.1	2.3	3.1	3.5
Lebanon	40.8	37.5	33.7	53.4	57.4	60.5	5.8	5.1	5.8
Malaysia	44.9	36.7	30.8	50.9	59.5	64.6	4.2	3.9	4.5
Mongolia	41.6	41.0	35.0	54.3	55.6	60.8	4.0	3.3	4.2
Nepal	38.4	43.3	39.6	57.7	53.8	57.0	3.9	2.9	3.5
Oman	43.3	44.2	43.3	54.0	53.4	53.9	2.7	2.5	2.8
Pakistan	43.7	44.2	39.2	51.8	53.0	57.9	4.4	2.8	3.0
Philippines	46.9	38.6	32.9	49.5	58.3	63.0	3.6	3.1	4.1
Qatar	39.0	33.8	37.1	58.3	63.6	58.7	2.7	2.6	4.3
Saudi Arabia	43.3	43.1	42.6	53.4	54.1	54.5	3.3	2.7	2.9
Singapore	43.2	24.8	21.4	54.7	70.1	71.6	2.1	5.1	7.0
Sri Lanka	42.1	34.2	28.3	54.3	61.4	65.7	3.6	4.4	5.9
Syrian Arab Rep	44.4	47.5	45.7	51.8	49.3	51.3	3.8	3.2	3.0
Thailand	45.6	36.7	29.4	51.0	60.0	66.1	3.3	3.3	4.5
Turkey	41.2	37.1	33.8	55.2	58.6	60.9	3.5	4.2	5.4
United Arab Emirates	43.7	30.7	27.6	53.0	66.8	68.6	3.4	2.4	3.8
Viet Nam	39.7	40.2	32.3	56.4	55.9	63.0	3.8	3.9	4.7
Yemen	42.4	45.3	44.6	54.4	51.4	51.9	3.2	3.3	3.5
Yemen, Dem	44.8	45.2	44.5	52.4	52.1	52.6	2.9	2.7	2.9
EUROPE	**25.8**	**20.9**	**19.3**	**64.5**	**66.6**	**66.1**	**9.7**	**12.4**	**14.5**
Albania	41.1	35.4	31.3	53.7	59.7	62.8	5.2	4.9	5.9
Austria	22.1	18.3	17.8	65.8	67.5	67.0	12.0	14.2	15.2
Belgium	23.5	18.7	17.1	64.5	68.0	67.0	12.0	13.3	15.9
Bulgaria	26.1	22.3	20.6	66.4	66.3	63.9	7.5	11.4	15.5
Czechoslovakia	27.4	24.5	21.7	64.0	64.4	66.0	8.6	11.1	12.3
Denmark	25.2	18.8	16.0	64.2	66.4	68.6	10.6	14.8	15.4
Finland	30.4	19.0	16.9	62.4	68.7	68.9	7.2	12.3	14.1
France	26.4	20.9	19.0	62.0	66.7	66.2	11.6	12.4	14.8
German Dem Rep	21.1	18.5	17.4	65.2	67.5	68.0	13.7	14.0	14.6
Germany, Fed Rep	21.3	15.7	15.9	67.8	70.3	67.6	10.8	14.0	16.5
Greece	26.5	21.9	21.9	65.3	64.8	62.3	8.3	13.3	15.6
Hungary	25.3	21.8	18.7	65.6	65.8	66.6	9.0	12.3	14.7
Ireland	31.1	30.5	26.9	57.7	58.6	63.8	11.2	10.9	9.4
Italy	24.9	19.9	18.0	65.8	66.7	65.8	9.3	13.4	16.2
Luxembourg	21.3	17.5	15.8	67.8	69.1	68.5	10.8	13.5	15.7
Malta	36.8	23.9	21.3	55.9	67.1	68.6	7.3	9.0	9.9
Netherlands	30.0	19.0	16.3	61.0	69.0	69.6	9.0	11.9	14.1
Norway	25.9	20.1	17.2	63.0	64.5	67.5	11.1	15.5	15.3
Poland	33.5	25.0	21.6	60.8	65.6	66.1	5.8	9.4	12.3
Portugal	29.2	24.8	22.2	62.9	64.7	65.9	8.0	10.4	11.9
Romania	28.2	25.1	23.1	65.1	65.4	64.1	6.7	9.6	12.8
Spain	27.4	24.6	22.7	64.4	64.3	63.9	8.2	11.1	13.5
Sweden	22.0	17.8	15.5	66.0	65.2	67.3	12.0	17.0	17.2
Switzerland	23.6	15.7	12.0	66.3	68.6	67.4	10.1	15.7	20.6
United Kingdom	23.3	19.3	19.1	65.1	66.0	66.0	11.7	14.7	14.9
Yugoslavia	30.5	23.4	20.3	63.2	68.1	66.9	6.3	8.4	12.9
USSR	**30.7**	**24.8**	**23.6**	**62.6**	**65.9**	**64.5**	**6.8**	**9.3**	**11.9**
OCEANIA	**32.9**	**28.4**	**26.1**	**59.6**	**63.4**	**64.8**	**7.4**	**8.2**	**9.1**
Australia	30.1	24.2	22.0	61.4	66.1	67.0	8.5	9.7	11.0
Fiji	48.0	35.5	30.1	49.5	60.9	64.9	2.5	3.5	5.0
New Zealand	32.9	24.7	22.3	58.5	65.7	67.3	8.6	9.6	10.5
Papua New Guinea	40.5	42.6	38.5	56.6	54.1	57.8	2.9	3.3	3.7
Solomon Islands	X	X	X	X	X	X	X	X	X
ANTARCTICA									

Source: U.N. Department of International Economic and Social Affairs.
0=zero or less than one-half the unit of measure; X=not available.
For additional information, see Sources and Technical Notes.

Table 2.4 HEALTH INDICATORS, 1960–85

	Estimated Infant Mortality (per thousand live births)		Minimum Daily Calorie Requirement	Daily Calorie Supply as Percentage of Requirement			Percentage of Married Couples of Childbearing Age Using Contraception	
	1960–65	1980–85		1964–66	1974–76	1980–82	1970	1982
WORLD	**117**	**81**						
AFRICA	**157**	**114**						
Algeria	160	109	2400	77	90	110	X	7
Angola	200	149	2350	81	88	99	X	X
Benin	200	149	2300	92	87	94	X	18
Botswana	111	79	2320	85	90	106	X	X
Burkina Faso	200	149	2370	86	83	81	X	1
Burundi	172	137	2330	96	96	102	X	1
Cameroon	160	117	2320	87	102	93	X	11
Cape Verde	115	77	2350	76	94	116	X	X
Central African Rep	189	143	2260	94	99	95	X	X
Chad	189	143	2380	100	74	75	X	1
Comoros	128	88	2340	95	95	98	X	X
Congo	166	124	2220	102	102	111	X	X
Djibouti	X	X	X	X	X	X	X	X
Egypt	160	113	2510	103	112	130	X	24
Equatorial Guinea	183	137	X	X	X	X	X	X
Ethiopia	170	143	2330	90	79	95	X	2
Gabon	151	112	2340	88	104	119	X	X
Gambia	220	193	2380	99	90	93	X	X
Ghana	137	98	2300	87	94	72	X	10
Guinea	202	159	2310	89	89	81	X	1
Guinea-Bissau	183	143	2310	86	94	97	X	X
Ivory Coast	166	122	2310	110	102	115	X	3
Kenya	130	82	2320	97	94	88	6	8
Lesotho	141	110	2280	90	90	103	X	5
Liberia	154	112	2310	104	95	98	X	X
Libya	150	92	2360	84	147	160	X	X
Madagascar	104	67	2270	106	111	111	X	X
Malawi	205	165	2320	91	98	96	X	1
Mali	189	149	2350	88	83	74	X	1
Mauritania	176	137	2310	89	78	95	X	1
Mauritius	61	32	2270	105	111	124	X	X
Morocco	154	99	2420	94	107	109	X	26
Mozambique	154	110	2340	86	85	80	X	1
Niger	186	140	2350	91	84	105	X	1
Nigeria	157	114	2360	95	94	104	X	6
Rwanda	143	110	2320	75	88	91	X	1
Senegal	177	141	2380	101	94	99	X	4
Sierra Leone	232	200	2300	88	85	84	X	4
Somalia	170	143	2310	91	91	90	X	1
South Africa	129	92	2450	111	119	117	X	X
Sudan	165	118	2350	79	91	99	X	5
Swaziland	150	129	2320	87	106	109	X	X
Tanzania, United Rep	145	98	2320	85	90	105	X	1
Togo	170	113	2300	97	89	94	X	X
Tunisia	152	85	2390	94	110	115	X	41
Uganda	132	94	2330	95	88	76	X	1
Zaire	146	107	2220	97	102	96	X	3
Zambia	144	101	2310	89	99	90	X	1
Zimbabwe	111	70	2390	88	89	91	X	22
NORTH AMERICA	**43**	**27**						
Barbados	61	23	2420	108	120	127	X	X
Canada	26	11	2660	120	125	129	X	X
Costa Rica	81	20	2240	104	114	118	X	65
Cuba	60	20	2310	102	116	126	X	79
Dominican Rep	110	64	2260	83	93	95	X	46
El Salvador	128	71	2290	80	90	92	X	34
Guatemala	115	68	2190	92	95	96	X	18
Haiti	170	108	2260	88	86	84	X	20
Honduras	137	82	2260	87	92	96	X	27
Jamaica	54	28	2240	98	116	113	X	51
Mexico	86	53	2330	111	117	126	X	39
Nicaragua	136	85	2250	111	109	100	X	9
Panama	63	26	2310	99	104	103	X	61
Trinidad and Tobago	48	28	2420	95	102	121	44	52
United States	25	12	2640	127	133	138	65	76
SOUTH AMERICA	**101**	**64**						
Argentina	60	36	2650	121	127	127	X	X
Bolivia	164	124	2390	77	84	89	X	24
Brazil	109	X	2390	102	104	108	X	50
Chile	111	40	2440	109	108	111	X	43
Colombia	85	53	2320	93	100	109	X	55
Ecuador	132	77	2290	84	91	91	X	40
Guyana	62	35	2270	105	104	103	X	X
Paraguay	81	45	2310	113	118	123	X	35
Peru	136	99	2350	96	95	91	X	41
Suriname	63	31	2260	104	108	111	X	X
Uruguay	48	38	2670	105	111	105	X	X
Venezuela	77	39	2470	92	95	104	X	49

Table 2.4

	Estimated Infant Mortality (per thousand live births)		Minimum Daily Calorie Requirement	Daily Calorie Supply as Percentage of Requirement			Percentage of Married Couples of Childbearing Age Using Contraception	
	1960–65	1980–85		1964–66	1974–76	1980–82	1970	1982
ASIA	**133**	**87**						
Afghanistan	228	205	2440	92	88	84	2	X
Bahrain	110	37	X	X	X	X	X	X
Bangladesh	156	133	2210	90	83	83	X	25
Bhutan	189	144	2310	X	X	X	X	X
Burma	150	94	2160	92	102	109	X	5
China	115	38	2360	86	93	106	X	71
Cyprus	29	17	2480	107	122	138	X	X
India	157	118	2210	89	87	92	12	32
Indonesia	145	87	2160	82	95	109	X	58
Iran	156	101	2410	92	117	120	X	23
Iraq	130	72	2410	91	103	116	14	X
Israel	29	15	2570	110	120	118	X	X
Japan	24	8	2340	113	119	122	56	56
Jordan	126	63	2460	95	87	105	22	26
Kampuchea, Dem	140	160	2220	97	84	89	X	X
Korea, Dem People's Rep	71	32	2340	97	116	131	X	X
Korea, Rep	71	29	2350	96	117	125	25	58
Kuwait	77	30	X	X	X	X	X	X
Lao People's Dem Rep	150	122	2220	87	84	89	X	X
Lebanon	62	48	2480	100	104	120	53	X
Malaysia	63	29	2240	62	111	118	33	42
Mongolia	97	50	2430	106	105	113	X	X
Nepal	189	144	2200	91	91	91	X	7
Oman	184	122	X	X	X	X	X	X
Pakistan	153	120	2310	77	89	97	6	14
Philippines	97	50	2260	82	94	106	15	48
Qatar	120	45	X	X	X	X	X	X
Saudi Arabia	174	103	2420	80	83	123	X	X
Singapore	30	11	2300	111	130	128	60	71
Sri Lanka	65	38	2220	100	92	98	X	55
Syrian Arab Rep	124	57	2480	90	103	125	X	23
Thailand	95	51	2220	94	100	104	15	59
Turkey	176	110	2520	105	116	121	32	38
United Arab Emirates	120	45	X	X	X	X	X	X
Viet Nam	150	90	2160	93	95	93	X	21
Yemen	205	154	2420	93	92	104	X	1
Yemen, Dem	202	138	2410	84	80	94	X	X
EUROPE	**37**	**16**						
Albania	95	43	2410	101	113	121	X	X
Austria	32	13	2630	125	126	133	X	X
Belgium	27	11	2640	133	139	140	X	X
Bulgaria	36	20	2500	137	141	147	X	76
Czechoslovakia	23	16	2470	138	138	142	X	95
Denmark	20	8	2690	126	125	139	67	X
Finland	19	7	2710	116	116	117	77	80
France	25	10	2520	134	137	141	64	79
German Dem Rep	31	12	2620	124	134	142	X	X
Germany, Fed Rep	28	13	2670	115	120	126	X	X
Greece	50	19	2500	124	141	143	X	X
Hungary	44	21	2630	120	130	133	67	74
Ireland	28	13	2510	137	142	153	X	X
Italy	40	14	2520	126	140	141	X	78
Luxembourg	29	11	X	X	X	X	X	X
Malta	34	15	2480	111	123	118	X	X
Netherlands	16	8	2690	127	131	134	X	X
Norway	17	8	2680	115	116	124	X	71
Poland	51	21	2620	123	133	128	60	75
Portugal	76	25	2450	112	128	127	X	66
Romania	60	26	2650	113	125	126	X	58
Spain	42	12	2460	116	133	134	X	51
Sweden	15	7	2690	111	117	119	X	78
Switzerland	20	8	2690	126	122	129	X	X
United Kingdom	22	12	2520	134	129	129	69	77
Yugoslavia	80	29	2540	127	137	143	59	55
USSR	**32**	**25**	**2560**	**126**	**132**	**132**	**X**	**X**
OCEANIA	**55**	**39**						
Australia	20	11	2660	118	118	117	X	X
Fiji	63	28	2660	93	101	115	X	X
New Zealand	21	12	2640	131	136	136	X	X
Papua New Guinea	154	98	2660	73	77	79	X	5
Solomon Islands	X	X	2660	82	76	77	X	X
ANTARCTICA								

Sources: U.N. Food and Agriculture Organization, U.N. Department of International Economic and Social Affairs, World Health Organization, The World Bank.
0=zero or less than one-half the unit of measure; X=not available.
For additional information, see Sources and Technical Notes.

Table 2.5 EDUCATION, 1970–80

	Combined Primary and Secondary School Enrollment as Percentage of School-Age Population					
	Total		Male		Female	
	1970	1980	1970	1980	1970	1980
WORLD	**41**	**71**	**45**	**78**	**37**	**64**
AFRICA	**29**	**36**	**36**	**42**	**22**	**30**
Algeria	45	64	57	74	34	54
Angola	X	X	X	X	X	X
Benin	24	40	33	55	15	25
Botswana	47	73	44	66	49	79
Burkina Faso	7	11	9	14	5	8
Burundi	17	15	24	19	11	12
Cameroon	50	64	59	72	41	56
Cape Verde	X	X	X	X	X	X
Central African Rep	36	41	51	55	22	28
Chad	18	19	28	29	9	10
Comoros	19	64	26	77	12	52
Congo	X	X	X	X	X	X
Djibouti	X	X	X	X	X	X
Egypt	55	64	69	77	40	51
Equatorial Guinea	48	X	57	X	39	X
Ethiopia	11	28	15	37	7	20
Gabon	X	X	X	X	X	X
Gambia	16	32	23	42	10	22
Ghana	52	52	61	61	43	44
Guinea	24	25	34	35	14	16
Guinea-Bissau	29	58	40	82	18	36
Ivory Coast	37	49	47	61	25	36
Kenya	41	73	49	78	33	68
Lesotho	62	72	49	58	74	85
Liberia	31	45	43	58	20	33
Libya	X	X	X	X	X	X
Madagascar	50	54	55	58	46	50
Malawi	23	44	30	52	17	36
Mali	15	19	20	25	10	13
Mauritania	8	23	13	31	4	15
Mauritius	62	72	65	73	59	72
Morocco	32	48	42	59	22	36
Mozambique	X	47	X	55	X	39
Niger	7	14	10	18	5	10
Nigeria	21	X	27	X	16	X
Rwanda	41	45	47	48	36	43
Senegal	24	29	31	36	18	22
Sierra Leone	22	26	28	32	17	20
Somalia	7	23	11	31	3	17
South Africa	X	X	X	X	X	X
Sudan	24	36	30	42	18	29
Swaziland	63	81	65	82	61	81
Tanzania, United Rep	24	62	30	66	19	58
Togo	39	75	55	98	24	53
Tunisia	63	64	79	75	48	53
Uganda	25	33	31	38	19	28
Zaire	52	59	67	72	37	47
Zambia	61	67	69	73	53	61
Zimbabwe	47	56	52	60	42	52
NORTH AMERICA	**87**	**92**	**88**	**92**	**87**	**91**
Barbados	89	99	90	98	88	99
Canada	87	94	87	94	86	94
Costa Rica	76	80	76	79	77	81
Cuba	75	91	75	91	76	90
Dominican Rep	X	X	X	X	X	X
El Salvador	60	63	61	63	58	63
Guatemala	35	45	38	48	32	41
Haiti	X	43	X	47	X	40
Honduras	58	69	58	69	58	69
Jamaica	82	77	82	75	82	79
Mexico	67	88	70	89	63	86
Nicaragua	54	77	54	74	54	80
Panama	76	90	76	90	75	91
Trinidad and Tobago	83	79	82	77	84	80
United States	100	99	99	99	100	99
SOUTH AMERICA	**37**	**81**	**37**	**80**	**36**	**81**
Argentina	81	93	80	91	83	95
Bolivia	61	70	72	76	50	64
Brazil	X	77	X	76	X	77
Chile	88	96	86	95	89	96
Colombia	67	83	66	81	67	86
Ecuador	63	77	64	77	62	76
Guyana	79	78	80	77	79	78
Paraguay	67	66	70	69	64	64
Peru	72	89	78	93	66	84
Suriname	92	78	93	79	92	77
Uruguay	86	82	85	81	86	83
Venezuela	69	74	69	75	70	73

Table 2.5

	Combined Primary and Secondary School Enrollment as Percentage of School-Age Population					
	Total		Male		Female	
	1970	1980	1970	1980	1970	1980
ASIA	**28**	**71**	**33**	**80**	**22**	**61**
Afghanistan	19	26	32	41	5	10
Bahrain	83	81	94	85	71	75
Bangladesh	X	37	X	48	X	26
Bhutan	4	7	7	10	0	4
Burma	54	51	59	54	49	49
China	X	88	X	98	X	77
Cyprus	X	X	X	X	X	X
India	49	53	63	65	35	41
Indonesia	49	71	55	78	43	65
Iran	52	68	67	81	37	55
Iraq	49	90	68	101	29	78
Israel	83	88	83	86	83	91
Japan	92	98	93	97	92	98
Jordan	X	92	X	93	X	90
Kampuchea, Dem	X	X	X	X	X	X
Korea, Dem People's Rep	X	X	X	X	X	X
Korea, Rep	76	94	80	97	71	91
Kuwait	76	84	84	87	66	79
Lao People's Dem Rep	29	57	36	63	21	51
Lebanon	77	83	85	86	68	80
Malaysia	62	71	66	72	57	69
Mongolia	X	94	X	93	X	95
Nepal	18	44	30	64	6	23
Oman	X	41	X	54	X	27
Pakistan	25	35	37	50	13	18
Philippines	X	92	X	91	X	93
Qatar	77	87	80	84	71	93
Saudi Arabia	30	50	42	59	18	39
Singapore	77	79	79	79	74	80
Sri Lanka	71	74	72	74	69	73
Syrian Arab Rep	61	76	78	87	43	64
Thailand	58	65	61	67	55	62
Turkey	67	71	80	82	53	60
United Arab Emirates	65	86	75	84	48	91
Viet Nam	X	77	X	84	X	71
Yemen	7	27	14	49	1	7
Yemen, Dem	37	51	59	73	15	29
EUROPE	**81**	**85**	**82**	**84**	**80**	**86**
Albania	86	93	90	97	81	89
Austria	84	81	84	80	84	82
Belgium	92	95	93	94	92	95
Bulgaria	95	93	95	94	94	93
Czechoslovakia	76	78	73	74	78	82
Denmark	87	101	89	102	86	101
Finland	92	97	91	94	93	99
France	92	96	90	92	93	100
German Dem Rep	X	X	X	X	X	X
Germany, Fed Rep	78	79	78	78	78	80
Greece	85	91	90	94	81	89
Hungary	72	80	70	78	74	82
Ireland	92	97	91	95	93	100
Italy	81	84	85	85	77	83
Luxembourg	81	79	82	78	81	79
Malta	78	89	80	92	76	87
Netherlands	88	97	91	98	86	96
Norway	87	99	85	98	89	99
Poland	87	92	88	92	87	92
Portugal	80	88	84	89	77	88
Romania	87	93	89	94	85	92
Spain	88	97	91	96	85	97
Sweden	90	92	90	90	90	9[illegible]
Switzerland	X	X	X	X	X	X
United Kingdom	88	91	89	90	88	92
Yugoslavia	77	88	81	91	73	86
USSR	**X**	**X**	**X**	**X**	**X**	**X**
OCEANIA	**89**	**88**	**91**	**89**	**87**	**88**
Australia	101	99	101	99	100	100
Fiji	82	92	84	92	79	93
New Zealand	93	91	94	91	92	92
Papua New Guinea	32	40	40	46	24	33
Solomon Islands	X	X	X	X	X	X
ANTARCTICA						

Source: United Nations Educational, Scientific and Cultural Organization
0=zero or less than one-half the unit of measure; X=not available.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 2.1 Estimated Size and Growth of Population, 1960–2005

Source: U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

Population refers to the midyear population. Most data are estimates based on population censuses and surveys. All projections are for the medium-case scenario. (See discussion below.) The average annual growth rate of population takes into account the effects of international migration.

Many of the pre-1980 data in Tables 2.1–2.4 are estimated using models. Several kinds of demographic information are required to estimate the growth and composition of a country's population: the size of the population; age and sex distribution; fertility and mortality rates by age and sex groups; the growth rates of both the urban and rural populations; and levels of internal and international migration.

Recent population censuses and surveys have collected information needed to calculate or estimate the above indicators, although the degree of accuracy varies. The Population Division of the U.N. Department of International Economic and Social Affairs compiles and evaluates national census and survey reports from all countries. When necessary, the data are adjusted for underenumeration of certain age and sex groups (infants, female children, young males), misreporting of age and sex distributions, changes in definitions, etc. These adjustments incorporate information from civil registrations, population surveys, earlier censuses, other sources, and population models. (Because the figures have been adjusted, they are not strictly comparable to the official statistics compiled by the U.N. Statistical Office and published in the *Demographic Yearbook.*)

After the figures for size and age/sex composition of the population have been adjusted, the data are scaled to 1980. Because most countries conducted a population census or large-scale population survey in the 1970s or early 1980s, the scaling is usually minor. Similar estimates are made for each five-year period between 1980 and 1950. Historical data are used when deemed accurate, with adjustments and scaling similar to those described above. For many developing countries, however, accurate historical data do not exist. The Population Division estimates the main demographic parameters for these countries using available information and demographic models.

Projections are based on estimates of the 1980 base year population. Age- and sex-specific mortality rates are applied to the base year population to determine the number of survivors at the end of each five-year period. Future births are projected by applying age-specific fertility rates to the projected female population. The births are distributed by an assumed sex ratio, and the appropriate age- and sex-specific survival rates are applied. Future migration rates are also estimated on an age- and sex-specific basis. Combining future fertility, mortality, and migration rates yields the projected size and composition of the population.

Assumptions about future mortality, fertility, and migration—the three components of population growth—are made on a country-by-country basis and, whenever possible, are based on historical trends. Four scenarios of population growth (high, medium, low, and constant) are created using different assumptions about these rates. The medium-case scenario, for example, assumes medium levels of fertility, mortality, and migration, assumptions that may vary widely among the countries. The medium mortality assumption includes a quinquennial gain of 2.5 years in life expectancy at birth until it reaches 62.5 years. Life expectancy is assumed to increase more slowly thereafter. However, for the countries that have had little or no reduction in mortality recently (some sub-Saharan African and South Asian countries), the quinquennial gain in life expectancy was assumed to be 2 years or less. Refer to the source for further details.

Table 2.2 Births, Deaths, Fertility, and Mortality, 1950–85

Source: U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

The crude birth rate is the number of live births in a given year divided by the midyear population and multiplied by 1,000.

The crude death rate is the number of deaths in a given year divided by the midyear population and multiplied by 1,000.

The total fertility rate is an estimate of the number of children an average woman would have if current age-specific fertility rates remained constant during her reproductive years.

Life expectancy at birth is the average number of years a newborn baby is expected to live if the age-specific death rates effective at the year of its birth are applied.

For details on data collection, estimation, and projection methods, refer to the sources or to the Technical Note for Table 2.1.

Table 2.3 Age Distribution, 1960–2000

Source: U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

Age distribution estimates refer to the total population. The male and female age distributions differ from the age distribution of the total population and from each other. For details on methods of data collection, estimation, and projection, refer to the sources or to the Technical Note for Table 2.1.

Table 2.4 Health Indicators, 1960–85

Sources: Infant mortality: U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985). Minimum daily requirement of calories and calorie supply as percentage of requirements for 1980–82: U.N. Food and Agriculture Organization (FAO), *State of Food and Agriculture 1984* (FAO, Rome, 1985). Calorie supply as percentage of requirements for 1964–66 and 1974–76: FAO, *Production Yearbook 1983* (FAO, Rome, 1984). Percentage of married couples of childbearing age using contraception: The World Bank, *World Development Report 1985* (The World Bank, Washington, D.C., 1985).

The infant mortality rate is the number of babies who die before their first birthdays in a given year divided by the number of live births in that year and multiplied by 1,000.

The minimum daily calorie requirement is the energy intake necessary to meet the energy needs of an average healthy person. It is calculated for each country by the World Health Organization, which takes into account body size, age and sex distribution, physical activity level of the population, climate, and other factors.

The calorie supply as a percentage of requirements includes calories from all sources: domestic production, international trade, stock drawdowns, and foreign aid. The quantity of food available for human consumption, as estimated by FAO, is the food that reaches the consumer. The amount of food actually consumed may be lower than the figures show, depending on how much is lost in home storage, preparation, and cooking plus what is fed to pets and domestic animals or is thrown away.

The percentage of married couples using contraception includes women of childbearing age (or their husbands) who use any method of contraception. Data for 1970 refer approximately to 1968–72; data for 1982 refer generally to 1980–84.

Table 2.5 Education, 1970–80

Source: U.N. Statistical Office, *Selected Statistics and Indicators on the Status of Women* (United Nations, New York, 1985).

The number of students enrolled in primary and secondary schools is derived from the annual *Statistical Yearbook* of the U.N. Educational, Scientific and Cultural Organization. The age-specific population estimates are prepared by the Population Division of the U.N. Secretariat.

The combined primary and secondary enrollment rate is the ratio of total primary and secondary enrollment (regardless of age) to the number of persons in the primary and secondary age groups. The ratio may overstate the actual percentage of the population of primary- and secondary-age children enrolled because the denominator may not cover the entire range of ages covered by the numerator.

For example, the percentage of school-age children enrolled in school in Demark is reported in the tables as 101 percent. This indicates that some students are younger or older than the standard age groups used to form the demoninator.

Differences in the enrollment ratio may reflect the different definitions used, variations in the quality of the statistics, and different attendance patterns.

3. Human Settlements

This section provides data on two important aspects of human settlements: patterns of population distribution and living conditions.

Tables 3.1 and 3.3 include the latest estimates of the number of people living in urban and rural areas, the percentage living in cities over 100,000, and the 25 largest cities of the world.

As important as cities and towns have been throughout history, no single internationally recognized definition of urban population exists. As a result, countries supply the United Nations with data based on definitions shaped by local and national customs. Despite differences, however, these data indicate remarkable urban growth. The period between 1960 and 1985 saw an increase in the fraction of the population living in urban areas and rapid growth of cities of more than 100,000 people. But all population growth did not occur in cities and towns. Between 1980–85 rural populations grew in 46 of 49 African countries; 13 of 15 North and Central American countries; 7 of 12 in South America; 30 of 37 in Asia; and 3 of 26 in Europe.

The largest cities of the world increasingly appear in rapidly developing countries that support large, diverse labor forces. Most of these huge cities are still growing in population and area. They are doing so, though, at lower rates than 10 or 20 years ago. For instance, Mexico City grew by 92 percent between 1955 and 1965, by 75 percent between 1965 and 1975, and by 52 percent between 1975 and 1985.

Access to safe drinking water and sanitation is fundamental to development. Data for rural and urban populations, shown in Table 3.2, were compiled by the World Health Organization (WHO) for the International Drinking Water Supply and Sanitation Decade (1980–90). The data represent the situation in developing countries in the early 1980s. The information is the latest available from WHO's ongoing program to develop baseline information, establish targets, and assess progress in this field. Industrial countries are not included, but they routinely report that between 90 and 100 percent of their populations have access to safe drinking water and sanitation facilities.

Statistics on access to safe drinking water, particularly for rural areas, have been difficult to collect in a valid and reliable manner. Technical problems include defining what is meant by "access;" testing to determine safe levels of contaminants; determining if treatment facilities are operating; etc. Other problems stem from institutional and political conflicts. Some countries report high levels of access to demonstrate substantial progress in development. Others may report low levels to establish a record for seeking international aid for rural development and public water supply projects. Despite problems with the data, they show clearly that hundreds of millions of people do not have adequate access to safe drinking water and sanitation. Countries reporting especially poor access include Mali, Uganda, Bolivia, Paraguay, Nepal, Lao PDR, Bhutan, and Papua New Guinea.

One of the most costly environmental problems facing industrialized countries is the control of wastes, particularly hazardous wastes. Table 3.4 shows information on municipal, industrial, and hazardous wastes. The data shown for hazardous wastes are the amounts generated principally by industry. They are based on definitions, regulations, and collection methods unique to each country. In the United States, 32 of 50 states define hazardous waste (based on existing laws and regulations) differently from the U.S. Environmental Protection Agency. Since 1976, four major studies have estimated the total annual amount of hazardous waste produced in the United States. The results ranged from 41 million to 264 million metric tons per year. The high figure, based on studies completed in 1984, is believed to be the best approximation of the amount of hazardous waste that requires treatment or long-term safe disposal as mandated by the Resources Conservation and Recovery Act.

Table 3.1 POPULATION DISTRIBUTION, 1960–85

	Urban Population as Percentage of Total		Average Annual Population Growth Rate (percent)				Percentage of Total Population Living in Cities of over 100,000	
			Urban		Rural			
	1960	1985	1960–65	1980–85	1960–65	1980–85	1960	1980
WORLD	**33.6**	**41.6**	**3.1**	**2.5**	**1.3**	**1.1**		
AFRICA	**18.4**	**32.1**	**4.6**	**5.2**	**1.9**	**2.0**		
Algeria	30.4	66.6	6.2	5.1	-0.2	0.1	17.1	15.6
Angola	10.4	24.5	5.1	5.6	1.0	1.6	4.6	13.3
Benin	9.5	38.5	5.2	7.3	1.2	0.5	6.5	22.6
Botswana	1.8	19.2	18.6	8.0	2.2	2.5	0.3	5.9
Burkina Faso	4.7	7.9	3.7	4.7	1.5	2.1	2.5	6.2
Burundi	2.2	2.5	1.9	4.4	1.9	2.6	2.2	2.2
Cameroon	13.9	42.4	5.3	6.6	1.4	0.0	5.0	11.9
Cape Verde	7.0	6.1	1.6	2.2	2.9	1.3	X	X
Central African Rep	22.7	45.7	4.7	4.5	0.4	0.6	9.0	14.7
Chad	7.0	21.6	6.6	6.1	1.3	1.3	2.5	7.0
Comoros	5.1	14.0	6.5	6.8	2.0	2.5	X	X
Congo	33.0	39.5	2.6	3.7	1.8	1.9	33.1	37.1
Djibouti	X	X	X	X	X	0.0	49.2	70.7
Egypt	37.9	46.5	3.9	3.3	1.6	1.9	28.3	33.[illegible]
Equatorial Guinea	25.5	59.7	5.8	4.3	-0.5	-0.6	25.4	55.6
Ethiopia	6.4	17.6	5.7	6.5	2.1	1.9	2.5	6.8
Gabon	17.4	40.9	4.8	4.3	-0.1	0.0	6.6	24.1
Gambia	12.4	20.9	4.1	4.3	2.0	1.4	12.4	18.5
Ghana	23.3	39.6	5.1	5.2	2.0	2.0	11.0	19.0
Guinea	9.9	22.2	5.1	5.4	1.3	1.5	3.7	15.2
Guinea-Bissau	13.6	27.1	2.3	4.5	-1.1	1.0	4.9	8.6
Ivory Coast	19.3	42.0	7.4	5.9	2.8	1.8	6.6	15.4
Kenya	7.4	16.7	6.6	7.4	3.2	[illegible]	4.9	10.6
Lesotho	1.5	5.8	7.6	7.4	1.9	2.3	1.5	4.5
Liberia	18.6	39.5	6.0	5.6	1.7	1.7	9.3	15.9
Libya	22.7	64.5	6.5	6.4	2.8	-0.1	20.6	31.6
Madagascar	10.6	21.8	5.2	5.7	1.8	2.1	4.6	6.7
Malawi	4.4	12.0	4.6	7.6	2.3	2.7	1.6	4.3
Mali	11.1	20.8	4.5	5.3	1.6	2.2	3.5	7.5
Mauritania	6.7	34.6	9.9	8.0	1.7	0.7	0.5	16.8
Mauritius	33.2	56.8	5.4	3.6	2.0	-0.1	16.8	14.8
Morocco	29.3	43.9	4.4	4.9	2.0	2.1	26.7	31.4
Mozambique	3.7	19.4	6.5	10.9	1.9	1.5	2.8	6.0
Niger	5.8	16.2	6.1	6.9	2.7	2.1	1.1	4.1
Nigeria	13.1	23.0	5.0	5.8	2.4	2.7	9.7	17.6
Rwanda	2.4	5.1	5.8	6.8	2.9	3.3	X	X
Senegal	22.4	42.4	5.5	4.9	1.7	1.2	16.4	21.7
Sierra Leone	13.0	28.3	4.7	4.6	0.8	0.8	7.2	15.7
Somalia	17.3	34.1	4.9	6.2	1.3	2.6	6.3	11.2
South Africa	46.7	55.9	2.4	3.5	1.9	1.3	26.9	25.7
Sudan	10.3	29.4	6.8	6.3	1.4	1.6	4.3	9.7
Swaziland	3.9	26.3	12.4	8.7	1.8	1.3	2.1	5.1
Tanzania, United Rep	4.8	14.8	5.7	8.1	2.7	2.8	1.6	5.9
Togo	9.8	20.1	4.4	5.7	1.1	2.2	5.4	10.5
Tunisia	36.0	56.8	3.7	4.0	0.7	0.4	17.8	20.7
Uganda	5.2	14.4	8.3	7.3	3.8	2.9	2.0	6.1
Zaire	22.3	44.2	5.0	5.2	0.9	1.3	10.0	23.1
Zambia	17.2	49.5	8.9	6.2	1.3	0.8	15.2	32.3
Zimbabwe	12.6	24.6	6.8	5.8	3.7	2.8	9.4	17.3
NORTH AMERICA	**63.2**	**70.0**	**2.5**	**1.8**	**0.7**	**0.7**		
Barbados	35.4	42.2	0.8	1.8	0.1	0.1	35.4	38.6
Canada	68.9	75.0	3.0	1.2	-0.9	1.2	44.2	55.0
Costa Rica	36.6	45.9	4.5	3.8	3.1	1.7	24.4	27.3
Cuba	54.9	71.8	3.1	1.7	0.9	-1.8	31.2	33.3
Dominican Rep	30.2	55.7	5.9	4.3	1.5	0.1	19.1	37.1
El Salvador	38.3	43.0	3.4	3.8	2.9	2.3	13.0	11.5
Guatemala	33.0	41.4	3.8	4.1	2.6	2.1	13.6	14.2
Haiti	15.6	28.0	4.5	4.9	1.6	1.7	6.6	13.9
Honduras	22.7	39.9	5.9	5.4	2.6	2.1	9.9	19.0
Jamaica	33.8	53.8	3.7	2.9	0.4	-0.3	26.1	33.1
Mexico	50.8	70.0	4.8	3.6	1.4	0.5	28.8	43.2
Nicaragua	39.6	59.4	4.7	4.7	2.1	1.5	14.1	28.5
Panama	41.2	51.9	4.4	2.9	1.6	1.5	28.2	37.7
Trinidad and Tobago	22.2	22.6	2.6	1.9	3.0	0.6	11.3	6.8
United States	70.0	74.2	2.0	1.0	0.2	0.5	52.4	56.5
SOUTH AMERICA	**51.7**	**72.4**	**4.3**	**3.3**	**0.8**	**–0.3**		
Argentina	73.6	84.6	2.2	2.0	-0.4	-0.7	53.0	58.3
Bolivia	39.3	43.7	2.7	3.3	2.0	2.2	19.4	28.6
Brazil	44.9	72.7	5.3	3.7	0.9	-1.3	28.3	43.0
Chile	67.8	83.4	3.4	2.2	-0.3	-0.8	36.0	47.5
Colombia	48.2	67.4	5.2	3.1	0.9	0.3	32.1	43.4
Ecuador	34.4	47.7	4.5	4.4	2.1	2.0	19.6	24.6
Guyana	29.0	32.2	2.7	3.0	2.5	1.5	26.4	20.9
Paraguay	35.6	41.5	2.9	4.0	2.3	2.3	15.8	17.3
Peru	46.3	67.4	5.2	3.5	0.7	0.9	26.5	41.3
Suriname	47.3	45.7	2.7	0.4	2.8	-0.3	35.9	20.8
Uruguay	80.1	85.0	1.4	0.9	0.2	-0.6	45.4	40.5
Venezuela	66.6	85.7	5.4	3.8	0.6	0.2	35.2	48.0

Table 3.1

	Urban Population as Percentage of Total		Average Annual Population Growth Rate (percent)				Percentage of Total Population Living in Cities of over 100,000	
			Urban		Rural			
	1960	1985	1960–65	1980–85	1960–65	1980–85	1960	1980
ASIA	**20.6**	**28.2**	**3.9**	**2.9**	**1.6**	**1.3**		
Afghanistan	8.0	18.5	5.2	3.4	1.8	-0.7	4.4	11.3
Bahrain	78.6	81.7	4.0	4.6	4.1	3.1	43.2	37.7
Bangladesh	5.1	11.9	6.3	5.4	2.2	2.4	3.8	7.8
Bhutan	2.5	4.5	4.0	4.9	1.8	1.9	X	X
Burma	19.3	30.0	4.0	4.5	1.9	1.7	8.2	11.1
China	16.8	21.0	4.4	1.9	1.2	1.0	11.5	11.1
Cyprus	35.6	49.5	1.7	2.5	0.5	0.1	16.5	18.9
India	18.0	25.5	3.4	3.7	2.3	1.4	10.7	14.4
Indonesia	14.6	25.3	3.7	4.4	1.9	0.9	11.0	14.3
Iran	33.6	55.0	5.2	4.7	2.4	1.1	21.5	31.2
Iraq	42.9	70.6	6.4	4.7	0.1	0.7	28.4	69.3
Israel	77.0	90.7	4.9	2.4	0.1	1.1	54.9	49.3
Japan	62.5	76.5	2.5	0.6	-1.7	0.3	33.7	45.6
Jordan	42.7	64.4	4.5	5.0	1.6	1.4	20.7	33.8
Kampuchea, Dem	10.3	15.6	3.5	5.2	2.3	2.5	7.2	6.9
Korea, Dem Peoples Rep	40.2	63.8	5.1	3.6	1.1	0.2	16.9	24.9
Korea, Rep	27.7	65.3	5.7	4.2	1.3	3.0	28.2	55.6
Kuwait	72.3	93.7	12.0	6.0	6.2	3.5	77.9	74.0
Lao Peoples Dem Rep	7.9	15.9	3.3	5.8	2.3	1.9	5.5	6.5
Lebanon	39.6	80.4	7.4	1.2	0.6	4.5	32.4	68.6
Malaysia	25.2	31.5	3.7	3.7	2.8	1.7	11.3	12.5
Mongolia	35.7	55.9	6.1	4.0	0.7	1.1	18.9	26.7
Nepal	3.1	5.8	4.3	5.3	1.8	2.2	1.3	1.4
Oman	3.5	8.8	6.2	8.2	2.3	4.2	2.7	4.2
Pakistan	22.1	29.8	3.9	4.3	2.3	2.6	12.1	17.9
Philippines	30.3	39.6	3.9	3.7	2.7	1.7	16.2	21.6
Qatar	72.4	88.0	10.0	4.5	5.6	1.0	72.4	86.1
Saudi Arabia	29.7	73.0	8.6	5.7	0.5	0.2	13.2	40.4
Singapore	77.6	74.2	2.5	1.3	3.8	1.2	77.6	74.1
Sri Lanka	17.9	21.1	4.5	1.6	1.9	2.2	8.9	8.2
Syrian Arab Rep	36.8	47.4	4.8	4.5	2.0	2.9	29.0	32.2
Thailand	12.5	15.6	3.6	3.8	2.9	1.8	8.2	9.9
Turkey	29.7	48.1	5.2	3.8	1.2	1.1	18.9	33.4
United Arab Emirates	40.0	77.6	16.3	5.0	3.0	9.2	11.5	23.4
Viet Nam	14.7	20.3	4.4	3.1	1.8	1.8	13.2	10.6
Yemen	3.4	20.0	10.1	7.8	1.8	1.2	1.8	3.2
Yemen, Dem	28.0	39.9	3.6	4.2	1.7	1.7	10.9	21.8
EUROPE	**60.5**	**73.3**	**1.8**	**0.9**	**-0.6**	**-1.3**		
Albania	30.6	39.3	4.0	3.5	2.5	1.4	8.3	9.3
Austria	49.9	56.1	0.9	0.5	0.2	-0.7	36.0	34.3
Belgium	84.6	89.2	1.1	0.1	-1.7	-0.6	29.8	26.4
Bulgaria	38.6	68.6	4.3	1.8	1.7	-2.2	16.5	25.3
Czechoslovakia	46.9	66.3	2.4	1.5	-0.9	-1.5	15.5	16.4
Denmark	73.7	85.9	1.7	0.5	2.0	2.2	38.2	35.8
Finland	38.1	66.9	3.5	1.8	1.4	2.3	16.1	24.7
France	62.4	77.2	2.8	0.8	1.4	1.4	40.0	46.3
German Dem Rep	72.3	78.2	0.1	0.3	0.8	1.5	23.2	24.8
Germany, Fed Rep	77.4	86.1	1.8	0.1	0.7	-2.1	52.9	54.1
Greece	42.9	65.9	2.6	1.8	1.2	1.6	31.5	40.7
Hungary	40.0	57.0	1.6	1.4	-0.6	1.4	23.8	29.7
Ireland	45.8	57.0	1.5	1.7	-0.8	0.3	27.4	19.9
Italy	59.4	71.7	1.5	0.9	0.6	1.4	40.6	49.7
Luxembourg	62.1	81.8	1.4	0.7	0.6	3.6	22.7	22.5
Malta	70.0	85.4	0.5	1.2	3.4	2.0	5.3	4.3
Netherlands	76.8	92.5	1.6	1.3	0.7	8.2	37.6	39.3
Norway	32.1	80.5	3.5	3.2	0.6	8.5	22.8	24.3
Poland	47.9	59.2	2.1	1.8	0.4	0.3	29.0	32.8
Portugal	22.5	31.2	2.4	1.8	0.4	0.2	15.0	17.5
Romania	34.2	54.8	2.6	2.4	0.4	-1.0	20.8	26.9
Spain	56.6	77.4	2.6	1.6	1.3	1.8	35.5	50.8
Sweden	72.6	85.5	1.9	0.3	-2.9	-1.7	25.9	46.3
Switzerland	51.0	60.4	2.5	0.5	1.0	-1.4	30.8	38.9
United Kingdom	85.7	91.7	1.1	0.2	-1.3	-2.1	70.3	67.8
Yugoslavia	27.9	46.3	3.3	2.5	0.1	-0.7	9.8	17.0
USSR	**48.8**	**66.3**	**2.9**	**1.9**	**0.0**	**-0.8**	**27.9**	**36.2**
OCEANIA	**66.3**	**71.7**	**2.8**	**1.5**	**0.7**	**1.4**		
Australia	80.6	86.8	2.6	1.4	0.6	0.5	60.0	73.1
Fiji	29.7	41.2	5.1	2.9	2.4	0.8	16.4	21.3
New Zealand	76.0	83.7	2.8	0.8	0.5	0.3	42.5	50.0
Papua New Guinea	2.7	14.3	15.4	4.5	1.7	2.4	1.1	4.1
Solomon Islands	X	X	X	X	X	X	6.0	8.1
ANTARCTICA								

Sources: U.N. Department of International Economic and Social Affairs; The World Bank.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 3.2 DRINKING WATER AND SANITATION, EARLY 1980s

	Percentage of Population with Access to Safe Drinking Water			Percentage of Population with Access to Sanitation Services		
	Total	Urban	Rural	Total	Urban	Rural
WORLD						
AFRICA						
Algeria	X	X	X	X	X	X
Angola	28	90	12	18	29	15
Benin	18	26	15	18	48	4
Botswana	55	98	47	33	90	23
Burkina Faso	31	27	31	7	38	5
Burundi	24	90	22	52	50	52
Cameroon	X	X	X	X	X	X
Cape Verde	31	99	27	10	49	8
Central African Rep	X	X	X	X	X	X
Chad	X	X	X	X	X	X
Comoros	X	X	X	X	X	X
Congo	20	42	7	X	X	X
Djibouti	40	80	40	18	75	18
Egypt	75	88	64	26	45	10
Equatorial Guinea	25	47	X	X	99	X
Ethiopia	X	X	X	X	X	X
Gabon	X	X	X	X	X	X
Gambia	48	100	36	X	X	X
Ghana	51	72	39	27	47	16
Guinea	15	69	2	11	54	1
Guinea-Bissau	33	21	37	15	6	18
Ivory Coast	X	X	X	X	X	X
Kenya	27	61	21	44	75	39
Lesotho	12	37	11	14	13	14
Liberia	38	71	20	21	24	20
Libya	96	100	90	88	100	72
Madagascar	21	73	9	X	3	X
Malawi	41	77	37	83	100	81
Mali	15	46	8	6	18	3
Mauritania	84	80	85	X	5	X
Mauritius	99	100	98	95	100	90
Morocco	X	100	X	X	X	X
Mozambique	X	X	X	X	X	X
Niger	34	41	33	7	36	3
Nigeria	36	60	30	X	30	X
Rwanda	60	55	60	60	60	60
Senegal	45	77	25	39	100	2
Sierra Leone	19	61	6	20	52	10
Somalia	34	65	21	18	48	5
South Africa	X	X	X	X	X	X
Sudan	48	100	31	X	73	X
Swaziland	X	X	X	X	X	X
Tanzania, United Rep	45	88	39	51	83	47
Togo	33	68	26	11	24	8
Tunisia	60	100	17	X	100	X
Uganda	16	45	12	13	34	10
Zaire	20	43	5	6	X	10
Zambia	47	65	33	70	100	48
Zimbabwe	X	X	X	X	X	X
NORTH AMERICA						
Barbados	51	100	18	X	1	X
Canada	X	X	X	X	X	X
Costa Rica	82	100	68	87	93	82
Cuba	X	X	X	X	X	X
Dominican Rep	59	85	32	25	41	9
El Salvador	51	67	40	48	80	26
Guatemala	51	90	26	36	48	28
Haiti	33	58	25	19	41	12
Honduras	68	91	55	44	50	40
Jamaica	X	X	X	X	X	X
Mexico	74	91	40	56	78	12
Nicaragua	55	91	10	19	35	X
Panama	83	100	65	45	62	28
Trinidad and Tobago	97	100	96	97	100	96
United States	X	X	X	X	X	X
SOUTH AMERICA						
Argentina	62	72	17	83	94	32
Bolivia	40	78	12	22	40	9
Brazil	75	86	53	X	33	X
Chile	85	100	18	82	100	4
Colombia	92	100	79	66	100	4
Ecuador	55	98	21	43	64	26
Guyana	72	100	60	86	100	80
Paraguay	24	46	10	87	92	84
Peru	53	73	18	37	57	1
Suriname	98	100	96	98	100	96
Uruguay	81	96	2	59	59	60
Venezuela	84	91	50	87	90	70

Table 3.2

	Percentage of Population with Access to Safe Drinking Water			Percentage of Population with Access to Sanitation Services		
	Total	Urban	Rural	Total	Urban	Rural
ASIA						
Afghanistan	21	39	18	X	3	X
Bahrain	100	100	100	100	100	100
Bangladesh	42	29	43	4	21	2
Bhutan	15	40	14	X	X	X
Burma	25	36	21	20	34	15
China	X	X	X	X	X	X
Cyprus	100	100	100	100	100	100
India	55	80	47	8	30	1
Indonesia	31	40	29	30	31	30
Iran	66	82	50	70	96	43
Iraq	82	100	46	71	100	15
Israel	X	X	X	X	X	X
Japan	X	X	X	X	X	X
Jordan	86	100	65	70	94	34
Kampuchea Dem	X	X	X	X	X	X
Korea Dem Peoples Rep	X	X	X	X	X	X
Korea Rep	75	86	61	100	100	100
Kuwait	X	X	X	X	X	X
Lao Peoples Dem Rep	21	28	20	5	13	4
Lebanon	X	X	X	X	X	X
Malaysia	79	97	71	71	100	59
Mongolia	X	X	X	X	X	X
Nepal	14	71	11	2	16	1
Oman	22	100	16	19	100	13
Pakistan	39	78	24	19	53	6
Philippines	54	53	55	57	75	47
Qatar	71	75	43	X	X	X
Saudi Arabia	89	100	68	78	100	33
Singapore	100	100	NA	74	100	NA
Sri Lanka	28	65	18	67	80	63
Syrian Arab Rep	79	100	61	47	66	29
Thailand	67	50	70	45	50	44
Turkey	77	95	62	25	56	X
United Arab Emirates	92	95	81	80	93	22
Viet Nam	X	X	31	X	X	70
Yemen	33	100	21	X	75	X
Yemen Dem	52	73	39	46	69	33
EUROPE						
Albania	X	X	X	X	X	X
Austria	X	X	X	X	X	X
Belgium	X	X	X	X	X	X
Bulgaria	X	X	X	X	X	X
Czechoslovakia	X	X	X	X	X	X
Denmark	X	X	X	X	X	X
Finland	X	X	X	X	X	X
France	X	X	X	X	X	X
German Dem Rep	X	X	X	X	X	X
Germany Fed Rep	X	X	X	X	X	X
Greece	X	X	X	X	X	X
Hungary	X	X	X	X	X	X
Ireland	X	X	X	X	X	X
Italy	X	X	X	X	X	X
Luxembourg	X	X	X	X	X	X
Malta	100	100	100	97	100	84
Netherlands	X	X	X	X	X	X
Norway	X	X	X	X	X	X
Poland	X	X	X	X	X	X
Portugal	X	X	X	X	X	X
Romania	X	X	X	X	X	X
Spain	X	X	X	X	X	X
Sweden	X	X	X	X	X	X
Switzerland	X	X	X	X	X	X
United Kingdom	X	X	X	X	X	X
Yugoslavia	X	X	X	X	X	X
USSR	X	X	X	X	X	X
OCEANIA						
Australia	X	X	X	X	X	X
Fiji	77	94	66	70	85	60
New Zealand	X	X	X	X	X	X
Papua New Guinea	16	55	10	14	91	3
Solomon Islands	50	96	45	26	80	21
ANTARCTICA						

Source: World Health Organization
NA = not applicable. X = not available.
For additional information, see Sources and Technical Notes.

Table 3.3 POPULATION OF THE WORLD'S 25 LARGEST URBAN AGGLOMERATIONS, 1985

Rank		1985 Population (millions)	Average Annual Percentage Change				Total Change 1950–85 (percent)
			1950–60	1960–70	1970–80	1980–85	
1	Mexico City, Mexico	18.1	5.3	5.9	5.0	3.8	484
2	Tokyo/Yokohama, Japan	17.2	4.8	3.4	1.3	0.2	157
3	São Paulo, Brazil	15.9	5.8	5.4	4.4	4.4	468
4	New York/Northeastern New Jersey, United States	15.3	1.4	1.4	-0.4	-0.4	23
5	Shanghai, China	11.8	0.4	0.6	0.3	0.0	15
6	Calcutta, India	11.0	2.3	2.6	3.0	3.0	150
7	Greater Buenos Aires, Argentina	10.9	2.8	2.0	1.7	1.5	106
8	Rio de Janeiro, Brazil	10.4	3.8	3.5	2.5	2.5	197
9	Seoul, Rep. of Korea	10.2	8.1	8.4	4.6	3.7	827
10	Greater Bombay, India	10.1	3.3	4.0	3.7	3.5	248
11	Los Angeles/Long Beach, United States	10.0	4.9	2.4	1.2	1.0	144
12	London, United Kingdom	9.8	0.3	-0.1	-0.6	-0.4	-6
13	Beijing, China	9.2	0.9	1.3	0.9	0.2	37
14	Rhein-Ruhr, Fed. Rep. of Germany	9.2	2.3	0.7	0.0	-0.2	33
15	Paris, France	8.9	2.7	1.4	0.6	0.2	62
16	Moscow, USSR	8.7	2.8	1.2	1.5	1.2	81
17	Cairo/Giza/Imbaba, Egypt	8.5	4.0	3.9	3.1	3.1	240
18	Osaka/Kobe, Japan	8.0	4.1	2.9	0.5	0.0	111
19	Jakarta, Indonesia	7.9	4.5	4.9	4.1	3.3	339
20	Tianjin, China	7.8	1.1	1.4	1.1	0.3	44
21	Delhi, India	7.4	5.1	4.6	5.1	4.6	429
22	Baghdad, Iraq	7.2	5.2	9.6	8.6	4.8	1100
23	Teheran, Iran	7.2	7.2	6.2	5.4	5.2	700
24	Manila, Philippines	7.0	3.7	4.6	5.2	3.1	338
25	Milan, Italy	7.0	2.3	2.2	1.7	1.2	94
Total — 25 Cities		**254.7**	**2.7**	**2.6**	**2.1**	**1.8**	**126**
World Population		**4842.0**	**1.9**	**2.0**	**1.9**	**1.7**	**93**
Largest 25 Cities as Percentage of World Total		**5.3**					

Source: U.N. Department of International Economic and Social Affairs.
0 = zero or less than one-half the unit of measure.
For additional information, see Sources and Technical Notes.

Table 3.4 WASTE GENERATION IN SELECTED COUNTRIES, 1980

	Municipal Waste Generation		Industrial Waste Generation		Hazardous and Special Wastes (thousand metric tons per year)
	Total (thousand metric tons per year)	Kilograms per Capita per Year	Total (thousand metric tons per year)	Metric Tons per Million $US of Industrial Gross Domestic Product	
Australia	10000	681	20000	X	X
Austria	1560	208	300	10	100
Belgium	3082	313	8000	186	915
Canada	12600	526	61000	730	3290
Denmark	2046	399	814	X	63
Finland	1200	290	X	X	87
France	15500	289	38205	163	2000
Germany, Fed. Rep.	20780	338	52469	X	4892
Greece	2500	259	X	X	X
Ireland	640	188	1200	X	X
Italy	14041	246	35000	207	X
Japan	40225	344	161677	379	768
Netherlands	5400	382	4869	79	280
New Zealand	1528	488	498	67	X
Norway	1700	415	2186	93	120
Portugal	1500	152	11200	1110	X
Spain	8028	215	X	X	X
Sweden	2500	301	4000	102	550
Switzerland	2146	337	X	X	100
United Kingdom	15816	282	89749	490	1500
United States	160000	703	400000	455	264000

Source: Organization for Economic Cooperation and Development.
X = not available.
Note: Industrial Gross Domestic Product is the portion of Gross Domestic Product contributed by industry.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 3.1 Population Distribution, 1960–85

Sources: Urban population and average annual growth rate: U.N. Department of International Economic and Social Affairs (UNDIESA), *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985). Population living in cities over 100,000: World Bank, *World Development Report 1985* (Oxford University Press, New York, 1985).

Urban population is defined as the portion of the total population residing in urban areas. The remainder of the population is defined as rural. However, the definition of urban area varies widely from country to country. (See Part II, Chapter 3, "Human Settlements," Box 3.1.) For a list of individual country definitions, see UNDIESA *Estimates and Projections of Urban, Rural, and City Populations, 1950–2025: The 1982 Assessment* (United Nations, New York, 1985).

The definition of a city with over 100,000 population also varies from country to country. Most national censuses collect population data on one of three settlement patterns: the urban agglomeration, the metropolitan area, or the city proper. The United Nations uses data for the urban agglomeration when available. An urban agglomeration is defined as the population contained within the contours of the contiguous territory inhabited at urban levels of residential density without regard to administrative boundaries. The metropolitan area includes the urban agglomeration as well as surrounding areas of lower population density. If neither of these is available, the city proper definition is used; this tends to underestimate the population. For additional information on methods of data collection and estimation, refer to the Technical Notes for Table 2.1 in Chapter 2 "Population and Health."

Table 3.2 Drinking Water and Sanitation, Early 1980s

Sources: World Health Organization (WHO), *The International Drinking Water Supply and Sanitation Decade Review of National Baseline Data: December 1980* (WHO, Geneva, 1984); and draft tables from *The International Drinking Water Supply and Sanitation Decade: Review of National Baseline Data: December 1983* (WHO, Geneva, in press, 1986).

Data were collected from national governments by the World Health Organization (WHO) in 1980 and again in 1983 by means of questionnaires. The questionnaires were answered by public health officials, WHO experts, and Resident Representatives of the United Nations Development Program. The data collection effort was used to develop baseline information with which to assess progress in meeting national goals set for the International Drinking Water Supply and Sanitation Decade. Ninety-three of the 113 developing countries shown in Table 3.2 responded to either the 1980 or the 1983 questionnaire. These countries represented about 94 percent of the population of the developing world, excluding China. This total included 37 countries in Africa, covering 78 percent of the population (excluding South Africa); 23 countries in the Americas, covering 97 percent of the developing country population; and 29 countries in Asia, covering 98 percent of the population, excluding China. The next round of data collection is set for 1986.

The definitions of urban and rural population were supplied by national governments. (See Notes to Table 3.1.)

The WHO defines reasonable access to safe drinking water in an urban area as piped water to a housing unit or to a public standpipe within 200 meters. In rural areas, reasonable access implies that a family member need not spend a disproportionate part of the day fetching water. "Safe" drinking water includes treated surface water and untreated water from protected springs, boreholes, and sanitary wells. Other sources are considered unsafe.

Urban areas with access to sanitation services were defined as urban populations served by connections to public sewers or household systems such as pit privies, pour-flush latrines, septic tanks, communal toilets, etc. Rural populations with access had adequate disposal such as pit privies, pour-flush latrines, etc.

The application of these definitions to the situation in a country is clearly open to a considerable degree of subjective judgement. Comparisons between countries may therefore be misleading because of varied interpretations of definitions as well as incomplete responses. WHO reports note that access to sanitation in rural areas is systematically under-reported; no alternative estimates have been provided.

Table 3.3 Population of the World's 25 Largest Urban Agglomerations, 1985

Sources: U.N. Department for International Economic and Social Affairs, *Estimates and Projections of Urban, Rural and City Populations, 1950–2025: The 1982 Assessment* (United Nations, New York, 1985), Tables A-12 and A-13, pp. 144–148.

The 25 largest cities are large urban agglomerations, composed, in most cases, of the central city, adjacent smaller cities and towns, and suburbs. City boundaries depend on local administrative boundaries, population densities, types of economic activity, and other characteristics. Rankings depend on the population living within the urban agglomeration boundaries as determined by local and national governments. Rankings would not necessarily be the same if uniform criteria were used. The estimates for the Chinese cities–Shanghai and Beijing–should be considered tentative. Results of the 1982 Chinese Census may lead to substantial revisions. Average annual percent changes were calculated using the compound growth formula.

Table 3.4 Waste Generation in Selected Countries, 1980

Sources: Waste data: Organization for Economic Co-operation and Development (OECD), *Environmental Data Compendium 1985* (OECD, Paris, 1985), pp. 147 and 153. Gross Domestic Product data: The World Bank, *World Development Report 1982* (Oxford University Press, New York, 1982), Table 2, p. 112.

Municipal waste is composed of trash collected from households, commercial establishments, and small industries. It includes refuse from markets and gardens if collected and disposed of by the municipality. Paper, cardboard, and plastic packaging comprise 25–50 percent of municipal waste, depending on local consumption and production patterns. Other municipal wastes include organic matter, metals, leather, textiles, wood, and rubber.

Industrial waste comprises chemical and non-chemical wastes. Amounts of industrial waste depend on the levels of industrial production, types of technology used, and the definition of waste used in the country.

Hazardous waste is that waste known to contain potentially harmful substances. (Nuclear wastes are not included in this table. See Table 8.3.)

Additional caveats concerning national waste estimates are as follows:

1. New Zealand—municipal waste includes demolition waste; industrial waste is non-chemical waste only.
2. Australia—special and hazardous wastes are included under industrial waste.
3. Netherlands — industrial waste covers that from enterprises that employ ten or more people only and includes office and canteen wastes; hazardous waste refers to "notifiable" wastes only.
4. Norway—industrial waste includes chemical waste only.
5. United Kingdom—industrial waste includes some agricultural wastes.
6. Canada—hazardous waste is measured in wet weight.
7. Denmark — includes only hazardous waste that has been legally disposed of.
8. France—hazardous waste is toxic or hazardous waste.

For a more detailed discussion of hazardous waste measurement in the United States, see *State of the Environment: An Assessment At Mid-Decade* (The Conservation Foundation, Washington, D.C., 1984) pp. 68–73.

4. Land Use and Cover

The tables in this section are intended to provide a global picture of land cover, land use, and natural disasters caused by land disturbances. Data with which to examine specific kinds of land use and cover in more detail are shown in the sections on food and agriculture, forests and rangeland, wildlife resources, oceans and coasts, and human settlements.

Data on land use, collected by the U.N. Food and Agriculture Organization (FAO), are shown in Table 4.1. They highlight country and regional changes in agriculture, forestry, and range management over the last 10 to 20 years. Because the FAO is principally concerned with the production of crops, forest products, and livestock, it classifies the rest of a country's land as "Other Land," which includes wetlands, tundra, deserts, cities and towns, roadways and transport facilities, and all other unclassified land. The table, therefore, cannot be used to analyze changes in settlement patterns, parks and protected areas, industry, energy and transport facilities, or other uses.

The statistics on percentage distribution show a picture of changing patterns of land use over the past 15 to 20 years. In 1983, Africa had about 6 percent of its total land area in arable and permanent cropland; the figure was 5 percent in 1965. This change represents roughly a 20 percent increase over the past 18 years. Of the 49 African countries shown in the table, 41 reported increases in arable and permanent cropland, with 12 having increases greater than 25 percent.

Changes in land use are net changes. In the United States, for example, bottomland-hardwood forest along the Mississippi River has been drained and planted with soybeans, while marginal cropland in the Northeast and Midwest has returned to woodland and forest. The total amount of arable and permanent cropland remains about the same, but different kinds of land are now under cultivation than in the 1950s.

The FAO depends principally on figures supplied by national governments. When governments do not provide figures, the FAO develops estimates from unofficial sources, other international organizations, and their own best judgements. Preparing these estimates on an annual basis is not easy. Short-term changes (one to five years) in land use are generally very poorly monitored at the national level. In its most recent *Production Yearbook*, for example, the FAO had to provide its own estimates of agricultural land use for all African countries. When countries report a rapidly growing population over an 18-year period, but no change in land use, the statistics are probably unreliable.

The FAO's baseline information on land use for most countries is drawn from the World Census of Agriculture. About every ten years, countries collect extensive data on agricultural land use, tenure, and holdings using classifications and methods designed by the FAO. With the completion of the 1980 Census—the results of 31 countries had been published as of May 1985—national governments and the FAO will be better able to estimate the extent of and changes in major land uses.

With the increasing availability of data from remote sensors on satellites and other platforms, broad structural changes in vegetative cover and land use (forests to grasslands, for example) can be monitored more precisely. This information will not replace the need for on-the-ground measurements; however, it will help analysts improve the identification of land suitable (and unsuitable) for cultivation, monitor the extent of settlements, identify areas of rapid deforestation, and more.

Table 4.2 provides statistics on the current extent and type of vegetation and the patterns of vegetation that prevailed before the widespread establishment of agriculture and urban centers. These data can be used to analyze long-term changes in forest and grassland and can be compared with changes in cultivated area.

Important land disturbances include earthquakes, volcanoes, land subsidence, and mud slides. With the rapid improvement in seismology and remote sensing, virtually all significant earthquakes and active volcanoes are known and many smaller earthquakes are recorded. Although there is a noticeable decline in the number of deaths from major earthquakes in a few regions, the overall totals still reflect the devastation of a few major events, such as the 1976 earthquake in Tangshan, China, that killed 240,000 people.

Table 4.1 LAND USE, 1964–85

	Area (thousand square kilometers)			Population Density (persons per square kilometer of total area)	Percentage Distribution							
					Arable Land and Permanent Cropland		Meadows and Permanent Pasture		Forests and Woodland		Other Land	
	Total	Land	Inland Water	1985	1964-66	1981-83	1964-66	1981-83	1964-66	1981-83	1964-66	1981-83
WORLD	**147922**	**144774**	**3148**	**36.2**	**10**	**11**	**24**	**24**	**33**	**31**	**33**	**33**
AFRICA	**30331**	**29664**	**667**	**18.2**	**5**	**6**	**26**	**26**	**25**	**23**	**43**	**44**
Algeria	2382	2382	0	9.2	3	3	16	14	1	2	80	81
Angola	1247	1247	0	7.0	3	3	23	23	44	43	30	31
Benin	113	111	2	35.6	13	16	4	4	44	35	39	45
Botswana	600	585	15	1.8	2	2	71	75	2	2	26	21
Burkina Faso	274	274	0	25.3	8	10	37	37	30	26	26	28
Burundi	28	26	2	166.4	39	51	25	36	2	2	35	11
Cameroon	475	469	6	20.4	12	15	19	18	58	54	11	13
Cape Verde	4	4	0	79.7	10	10	6	6	0	0	84	84
Central African Rep	623	623	0	4.1	3	3	5	5	64	64	28	28
Chad	1284	1259	25	3.9	2	3	36	36	17	16	45	46
Comoros	2	2	0	210.6	39	42	7	7	16	16	38	35
Congo	342	342	1	5.1	2	2	29	29	64	62	5	6
Djibouti	22	22	0	13.3	0	0	9	9	0	0	91	91
Egypt	1001	995	6	46.7	3	2	0	0	0	0	97	98
Equatorial Guinea	28	28	0	14.0	8	8	4	4	61	61	28	27
Ethiopia	1222	1101	121	29.8	11	13	42	41	27	24	20	22
Gabon	268	258	10	4.4	1	2	20	18	78	78	2	2
Gambia	11	10	1	56.9	13	16	9	9	30	20	48	55
Ghana	239	230	9	56.5	11	12	16	15	43	38	30	35
Guinea	246	246	0	22.1	6	6	12	12	49	43	33	39
Guinea-Bissau	36	28	8	24.6	9	10	46	46	39	38	6	6
Ivory Coast	322	318	4	30.4	8	12	9	9	60	28	22	50
Kenya	583	569	13	35.4	3	4	7	7	5	4	85	85
Lesotho	30	30	0	50.1	12	10	73	66	0	0	15	24
Liberia	111	96	15	19.7	4	4	2	2	40	39	54	55
Libya	1760	1760	0	2.0	1	1	6	8	0	0	93	91
Madagascar	587	582	6	17.1	4	5	58	58	27	23	10	14
Malawi	118	94	24	59.2	21	25	20	20	53	45	6	10
Mali	1240	1220	20	6.5	1	2	25	25	8	7	66	67
Mauritania	1031	1030	0	1.8	0	0	38	38	15	15	47	47
Mauritius	2	2	0	564.5	50	58	4	4	33	31	13	7
Morocco	447	446	0	52.9	16	19	28	28	12	12	44	42
Mozambique	802	784	18	17.6	3	4	56	56	22	19	18	21
Niger	1267	1267	0	4.8	2	3	8	7	3	2	87	88
Nigeria	924	911	13	103.1	32	33	21	23	21	16	26	28
Rwanda	26	25	1	232.2	26	41	34	18	13	11	27	31
Senegal	196	192	4	33.2	23	27	30	30	35	30	12	13
Sierra Leone	72	72	0	50.2	20	25	31	31	29	29	20	16
Somalia	638	627	10	8.7	2	2	46	46	15	14	37	38
South Africa	1221	1221	0	26.5	11	11	69	66	4	4	16	20
Sudan	2506	2376	130	8.6	5	5	24	24	24	20	47	51
Swaziland	17	17	0	37.4	8	8	78	67	8	6	6	19
Tanzania, United Rep	945	886	59	23.8	4	6	40	40	50	47	7	7
Togo	57	54	2	51.5	21	26	4	4	45	29	31	41
Tunisia	164	155	8	44.1	28	31	16	20	3	4	53	46
Uganda	236	200	36	66.5	24	30	25	25	32	30	19	15
Zaire	2345	2268	78	14.1	3	3	4	4	80	78	13	15
Zambia	753	741	12	8.9	7	7	47	47	30	27	17	18
Zimbabwe	391	387	4	22.4	5	7	13	13	62	62	20	19
NORTH AMERICA	**22415**	**21356**	**1059**	**17.9**	**12**	**13**	**17**	**17**	**33**	**32**	**38**	**39**
Barbados	0	0	0	616.3	77	77	9	9	0	0	14	14
Canada	9976	9221	755	2.6	4	5	2	3	34	35	59	57
Costa Rica	51	51	0	51.3	10	12	21	42	58	33	11	13
Cuba	115	115	0	87.7	17	29	25	22	14	17	45	32
Dominican Rep	49	48	0	128.1	22	30	43	43	14	13	21	14
El Salvador	21	21	0	263.9	32	35	29	29	9	6	30	29
Guatemala	109	108	0	77.2	14	16	12	12	48	40	26	31
Haiti	28	28	0	237.3	22	33	18	18	3	4	57	46
Honduras	112	112	0	39.0	13	16	30	30	47	35	9	19
Jamaica	11	11	0	211.4	25	25	22	19	28	28	24	29
Mexico	1973	1923	50	40.0	12	12	39	39	29	25	20	24
Nicaragua	130	119	11	25.2	10	11	35	42	52	36	3	11
Panama	77	76	1	28.3	7	8	14	15	61	54	18	23
Trinidad and Tobago	5	5	0	217.9	27	31	1	2	48	44	24	23
United States	9363	9127	236	25.4	20	21	28	26	32	30	20	23
SOUTH AMERICA	**17819**	**17535**	**284**	**15.1**	**6**	**8**	**24**	**26**	**57**	**53**	**13**	**13**
Argentina	2767	2737	30	11.0	11	13	53	52	22	22	14	13
Bolivia	1099	1084	14	5.8	2	3	26	25	55	52	18	20
Brazil	8512	8457	55	15.9	6	9	15	19	71	67	8	5
Chile	757	749	8	16.0	6	7	14	16	21	21	60	56
Colombia	1139	1039	100	25.2	5	5	29	29	63	50	4	16
Ecuador	284	277	7	33.1	9	9	8	15	62	52	21	24
Guyana	215	197	18	4.4	2	3	5	6	92	83	1	8
Paraguay	407	397	9	9.0	2	5	35	39	54	52	9	4
Peru	1285	1280	5	15.3	2	3	21	21	58	55	18	21
Suriname	163	161	2	2.2	0	0	0	0	96	96	3	3
Uruguay	176	174	3	17.1	8	8	79	79	3	4	9	10
Venezuela	912	882	30	20.2	4	4	18	20	45	39	33	37

Table 4.1

	Area (thousand square kilometers)			Population Density (persons per square kilometer of total area)	Percentage Distribution							
					Arable Land and Permanent Cropland		Meadows and Permanent Pasture		Forests and Woodland		Other Land	
	Total	Land	Inland Water	1985	1964-66	1981-83	1964-66	1981-83	1964-66	1981-83	1964-66	1981-83
ASIA	**27575**	**26791**	**784**	**102.4**	**16**	**17**	**25**	**24**	**21**	**21**	**38**	**38**
Afghanistan	648	648	0	22.6	12	12	46	46	3	3	38	38
Bahrain	1	1	0	695.2	3	3	6	6	0	0	90	90
Bangladesh	144	134	10	702.4	67	68	4	4	17	16	12	11
Bhutan	47	47	0	30.1	1	2	4	5	66	70	28	24
Burma	677	658	19	58.4	16	15	1	1	49	49	35	35
China	9597	9326	271	110.8	11	11	31	31	11	14	47	45
Cyprus	9	9	0	72.1	47	47	10	10	19	19	25	25
India	3288	2973	314	231.5	55	57	5	4	20	23	20	17
Indonesia	1905	1812	93	86.6	10	11	7	7	68	67	15	15
Iran	1648	1636	12	27.4	9	8	27	27	11	11	53	54
Iraq	435	434	1	36.0	11	13	9	9	4	3	75	75
Israel	21	20	0	206.9	20	21	40	40	5	6	35	33
Japan	372	371	1	322.5	16	13	0	2	69	68	15	17
Jordan	98	97	1	35.9	4	4	1	1	0	0	95	94
Kampuchea, Dem	181	177	5	40.8	16	17	3	3	76	76	5	4
Korea, Dem Peoples Rep	121	120	0	166.6	16	19	0	0	74	74	9	6
Korea, Rep	98	98	0	415.0	23	22	0	1	68	67	9	11
Kuwait	18	18	0	100.2	0	0	8	8	0	0	92	92
Lao People's Dem Rep	237	231	6	18.7	4	4	3	3	63	55	30	37
Lebanon	10	10	0	256.5	28	29	1	1	9	7	61	63
Malaysia	330	329	1	47.2	11	13	0	0	79	67	10	20
Mongolia	1565	1565	0	1.2	1	1	89	79	10	10	1	11
Nepal	141	137	4	117.1	13	17	12	13	33	33	41	37
Oman	212	212	0	5.8	0	0	5	5	0	0	95	95
Pakistan	804	779	25	126.5	25	26	6	6	3	4	66	64
Philippines	300	298	2	182.4	31	38	3	4	57	41	10	17
Qatar	11	11	0	27.4	0	0	5	5	0	0	95	95
Saudi Arabia	2150	2150	0	5.2	0	1	40	40	1	1	59	59
Singapore	1	1	0	4434.5	23	11	0	0	7	5	70	84
Sri Lanka	66	65	1	250.0	28	34	4	7	49	37	19	23
Syrian Arab Rep	185	184	1	57.1	35	31	42	45	3	3	20	21
Thailand	514	512	2	100.3	25	37	1	1	51	31	24	31
Turkey	781	771	10	64.0	34	36	14	12	26	26	25	26
United Arab Emirates	84	84	0	15.7	0	0	2	2	0	0	98	97
Viet Nam	330	325	4	180.4	18	21	1	6	43	38	38	36
Yemen	195	195	0	33.6	14	14	36	36	8	8	42	42
Yemen, Dem	333	333	0	6.4	1	1	27	27	8	7	64	65
EUROPE	**4871**	**4728**	**143**	**101.0**	**28**	**30**	**20**	**18**	**32**	**33**	**20**	**19**
Albania	29	27	1	106.1	19	26	26	20	46	45	9	9
Austria	84	83	1	89.3	21	19	27	25	38	39	14	17
Belgium	33	33	0	298.5	30	25	24	21	21	21	24	33
Bulgaria	111	111	0	83.1	41	38	11	18	33	35	15	9
Czechoslovakia	128	125	2	122.4	42	41	14	13	35	37	9	9
Denmark	43	42	1	119.4	64	62	8	6	11	12	18	20
Finland	337	305	32	14.5	8	8	0	0	72	76	20	15
France	547	546	1	99.8	38	34	25	23	23	27	15	16
German Dem Rep	108	106	2	153.6	47	47	14	12	28	28	12	13
Germany, Fed Rep	249	244	4	245.8	31	31	22	19	30	30	17	20
Greece	132	131	1	75.3	29	30	39	40	20	20	12	10
Hungary	93	92	1	116.1	61	57	14	14	15	18	9	11
Ireland	103	100	3	34.9	18	14	64	70	3	5	15	11
Italy	301	294	7	188.8	52	42	17	17	21	22	10	19
Luxembourg	X	X	X	X	X	X	X	X	X	X	X	X
Malta	0	0	0	1193.8	44	44	0	0	0	0	56	56
Netherlands	37	34	3	388.8	29	25	39	34	9	9	24	32
Norway	324	308	16	12.8	3	3	1	0	23	27	73	70
Poland	313	305	8	120.1	52	49	14	13	26	29	8	9
Portugal	92	92	0	109.4	46	39	6	6	36	40	13	16
Romania	238	230	7	97.1	46	46	19	19	28	28	8	8
Spain	505	499	5	77.3	0	41	41	21	45	31	14	6
Sweden	450	412	38	18.4	8	7	2	2	64	64	27	27
Switzerland	41	40	2	152.3	10	10	44	40	25	26	21	23
United Kingdom	245	242	3	227.3	25	29	55	48	8	9	12	14
Yugoslavia	256	255	0	90.7	33	31	25	25	34	37	8	8
USSR	**22402**	**22272**	**130**	**12.4**	**10**	**10**	**17**	**17**	**41**	**41**	**32**	**32**
OCEANIA	**8510**	**8429**	**81**	**2.9**	**5**	**6**	**55**	**55**	**22**	**18**	**19**	**21**
Australia	7687	7618	69	2.0	5	6	59	59	18	14	18	21
Fiji	18	18	0	37.4	11	13	4	3	65	65	20	19
New Zealand	269	269	0	12.2	2	2	48	54	27	37	23	7
Papua New Guinea	462	452	10	8.0	1	1	0	0	72	71	27	28
Solomon Islands	28	28	1	9.6	2	2	1	1	93	93	4	4
ANTARCTICA	**14000**	**14000**	**0**									

Source: U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 4.2 LAND USE AND COVER, PREAGRICULTURE TO PRESENT

	Preagricultural Area (million square kilometers)	Present Area (million square kilometers)	Absolute Amount Converted to Cultivation (million square kilometers)	Percentage Converted to Cultivation
TOTAL ICE-FREE LAND AREA	**132.51**	**115.05**	**17.46**	**13.00**
FOREST	**49.86**	**42.10**	**7.76**	**15.56**
Tropical evergreen rainforest, mangrove	12.80	12.30	0.50	4.00
Tropical/subtropical evergreen seasonal broadleaved forest	4.09	3.33	0.76	19.00
Subtropical evergreen rainforest	0.22	0.19	0.03	14.00
Temperate/subpolar evergreen rainforest	0.43	0.39	0.04	9.00
Temperate evergreen seasonal broadleaved forest, summer rain	1.20	0.81	0.39	32.00
Evergreen broadleaved sclerophyllous forest, winter rain	0.64	0.47	0.17	27.00
Tropical/subtropical evergreen needleleaved forest	0.53	0.50	0.03	6.00
Temperate/subpolar evergreen needleleaved forest	9.63	9.29	0.34	4.00
Tropical/subtropical drought-deciduous forest	3.95	2.95	1.00	25.00
Cold-deciduous forest, with evergreens	7.75	5.18	2.57	33.00
Cold-deciduous forest, without evergreens	5.52	3.99	1.53	28.00
Xeromorphic forest/woodland	3.10	2.70	0.40	13.00
WOODLAND	**12.32**	**10.44**	**1.88**	**15.26**
Evergreen broadleaved sclerophyllous woodland	2.33	1.71	0.62	27.00
Evergreen needleleaved woodland	2.64	2.51	0.13	5.00
Tropical/subtropical drought-deciduous woodland	4.72	3.72	1.00	21.00
Cold-deciduous woodland	2.63	2.50	0.13	5.00
SHRUBLAND	**13.12**	**12.15**	**0.97**	**7.39**
Evergreen needleleaved shrubland/thicket and dwarf shrubland	1.55	1.31	0.24	15.00
Evergreen needleleaved or microphyllous shrubland/thicket	0.71	0.67	0.04	6.00
Drought-deciduous shrubland/thicket & dwarf shrubland/thicket	0.99	0.84	0.15	15.00
Cold-deciduous subalpine/subpolar shrubland and dwarf shrubland	0.46	0.46	0.00	0.00
Xeromorphic shrubland/dwarf shrubland	9.41	8.87	0.54	6.00
TUNDRA	**7.35**	**7.35**	**0.00**	**0.00**
Arctic/alpine tundra, mossy bog	7.35	7.35	0.00	0.00
GRASSLAND	**34.01**	**27.45**	**6.56**	**19.29**
Tall/medium/short grassland with 10-40% tree cover	8.53	6.46	2.07	24.00
Tall/medium/short grassland with less than 10% tree cover or tuft-plant cover	4.19	3.66	0.53	13.00
Tall/medium/short grassland with shrub cover	10.72	9.35	1.37	13.00
Tall grassland, no woody cover	1.46	0.81	0.65	45.00
Medium grassland, no woody cover	1.49	0.79	0.70	47.00
Meadow/short grassland, no woody cover	7.34	6.10	1.24	17.00
Forb formations	0.28	0.28	0.00	0.00
DESERT (bare soil)	**15.85**	**15.58**	**0.27**	**2.00**

Source: *Journal of Climate and Applied Meteorology*
0 = zero or less than one-half the unit of measure.
For additional information, see Sources and Technical Notes

Table 4.3 MAJOR EARTHQUAKES, EVENTS AND DEATHS, 1900–85

	1900–09	1910–19	1920–29	1930–39	1940–49	1950–59	1960–69	1970–79	1980–85[a]	1900–85 Total
WORLD TOTAL										
Earthquakes	**127**	**110**	**120**	**135**	**164**	**163**	**219**	**212**	**100**	**1,350**
Deaths	**115,516**	**64,009**	**603,344**	**171,526**	**69,372**	**12,380**	**54,804**	**425,694**	**20,012**	**1,536,657**
WESTERN EUROPE AND SCANDINAVIA										
Earthquakes	1	0	0	0	2	2	3	2	1	11
Deaths	40	0	0	0	0	7	8	0	2	57
SOUTHERN AND EASTERN EUROPE										
Earthquakes	10	9	18	11	18	23	39	21	16	165
Deaths	68,874	32,166	1,887	1,613	1,070	945	1,611	2,682	3,150	113,998
AFRICA										
Earthquakes	0	0	4	3	3	4	12	3	2	31
Deaths	0	0	0	16	267	1,279	13525	14	5,443	20544
INDIAN OCEAN										
Earthquakes	0	0	4	1	0	1	3	0	1	10
Deaths	0	0	0	250	0	0	5	0	0	255
SOUTHWEST ASIA										
Earthquakes	9	10	15	15	27	23	34	35	21	189
Deaths	28,106	371	7,639	44,127	20,425	5,582	27,768	56,082	9,689	199,789
USSR										
Earthquakes	7	5	3	7	8	8	11	9	2	60
Deaths	6,262	490	3	148	20,209	1,251	125	1	0	28,489
EAST ASIA										
Earthquakes	10	10	15	33	21	5	5	11	6	116
Deaths	1,156	12,895	488,647	88,171	1,090	133	3,001	240,279	216	835,588
JAPAN AND NORTHWEST PACIFIC ISLANDS										
Earthquakes	22	15	14	18	12	16	22	17	7	143
Deaths	1,386	229	103,228	6,217	10,380	781	250	74	240	122,785
PHILIPPINES										
Earthquakes	13	2	1	2	3	4	2	10	1	38
Deaths	14	50	600	0	72	454	234	8,034	24	9,482
INDONESIA AND SOUTHWEST PACIFIC ISLANDS										
Earthquakes	17	25	9	16	17	16	24	35	14	173
Deaths	0	15,000	0	58	7	31	1,201	8,880	595	25,772
AUSTRALIA AND NEW ZEALAND										
Earthquakes	1	0	1	4	1	0	1	1	0	9
Deaths	0	0	17	256	0	0	3	0	0	276
PACIFIC OCEAN										
Earthquakes	1	2	1	0	2	2	0	3	1	12
Deaths	0	0	0	0	0	0	0	2	0	2
SOUTHERN AND WESTERN SOUTH AMERICA										
Earthquakes	7	15	12	7	23	24	26	27	10	151
Deaths	5,260	190	609	28,062	15,491	548	6,503	80,861	474	137,998
BRAZIL										
Earthquakes	0	0	0	0	0	1	1	0	0	2
Deaths	0	0	0	0	0	0	1	0	0	1
CARIBBEAN										
Earthquakes	3	3	1	2	5	5	6	5	2	32
Deaths	1,400	116	0	34	130	13	239	9	15	1,956
PACIFIC NORTH AMERICA										
Earthquakes	17	11	13	11	12	19	16	25	13	137
Deaths	3,018	2,501	662	2,570	49	1,323	215	28,774	102	39,214
ALASKA										
Earthquakes	8	2	2	0	4	4	5	4	0	29
Deaths	0	0	0	0	178	5	115	0	0	298
ATLANTIC NORTH AMERICA										
Earthquakes	1	1	4	5	2	5	3	1	2	24
Deaths	0	1	0	4	4	28	0	2	2	41
ATLANTIC OCEAN										
Earthquakes	0	0	2	0	3	1	6	3	1	16
Deaths	0	0	52	0	0	0	0	0	60	112
ANTARCTICA										
Earthquakes	0	0	1	0	1	0	0	0	0	2
Deaths	0	0	0	0	0	0	0	0	0	0
ARCTIC										
Earthquakes	0	0	0	0	0	0	0	0	0	0
Deaths	0	0	0	0	0	0	0	0	0	0

Source: U.S. National Oceanic and Atmospheric Administration.
0 = zero; a = 1985 data are for January through mid May only.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 4.1 Land Use, 1964–85

Sources: Land and land-use data: U.N. Food and Agriculture Organization, *FAO Production Yearbook 1983* and *1984* (U.N. Food and Agriculture Organization, Rome, 1984 and 1985), Table 1, and unpublished FAO data. Population data: U.N. Population Division, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

Data for land area and land use are provided to the FAO by national governments in response to annual FAO questionnaires. Where official information is lacking, the FAO prepares its own estimates or relies on unofficial data.

Area data for land and inland water are for 1982. Inland water area refers to major rivers and lakes. Total area is the sum of inland water and land area and excludes national claims to the continental shelf and exclusive economic zones. The world total therefore excludes the oceans.

Arable land includes land under temporary crops, temporary meadows, land used for market and kitchen gardens, and temporarily fallow land. Permanent cropland is land under crops that do not need to be replanted after each harvest: cocoa, coffee, rubber, fruit trees, vines, etc. (It excludes land used to grow trees for wood or timber.)

Permanent pasture is land used five or more years for cultivated or wild forage crops.

Forests and woodland includes land under natural or planted stands of trees as well as logged-over areas that will be reforested in the near future.

Other land includes unused land, built-on areas, wasteland, parks, roads, etc.

Antarctica is included in the world area figures; however, the population density and land distribution figures for the world refer to the six inhabited continents.

Several countries use definitions of total area and land use that differ from those used above. Refer to the sources for details.

Table 4.2 Land Use and Cover, Preagriculture to the Present

Source: Elaine Matthews, "Global Vegetation and Land Use: New High Resolution Data Bases for Climate Studies," *Journal of Climate and Applied Meteorology*, Vol. 22, pp. 474–487 (1983).

The author has developed two separate global geographic data bases: a vegetation data base of natural vegetation and a land-use data base of current land-use practices. The current extent of the world's natural and anthropogenic vegetation was calculated from the two data bases.

The vegetation data base provides information on preagricultural vegetation; the land-use data base (in conjunction with the vegetation data base) was used to calculate the amount of vegetation remaining. Both data bases were developed using cells of one degree latitude by one degree longitude. Cells in which there was less than 50 percent land were classified as water. Antarctica was excluded because vegetation is limited.

Vegetation was classified using the UNESCO classification system. This five-level scheme uses the following classification criteria: lifeform, density, seasonality (evergreen or deciduous), altitude, climate, and vegetation architecture. The UNESCO system is hierarchical, allowing a classification to have varying degrees of detail; for example, a vegetation type can be classified as a forest, an evergreen forest, a tropical evergreen forest, etc. This hierarchy allows aggregation and disaggregation to the limits of detail in the original data.

The UNESCO classification system identifies 225 vegetation types, of which the author used 178. These were aggregated into 30 broad categories for this table.

Approximately 40 sources, many of them national atlases, were used in compiling the land-use data base. The hierarchical land-use classification, which was developed by the author, took into account intensity and permanency of land-use activities. The land-use data base records the presence and type of agriculture in the one degree cells; 119 distinct land uses were identified. Different types of land use leave varying portions of the natural vegetation intact. For example, the author estimates that intensive subsistence rice cultivation and large-scale commercial cultivation leave 0 percent of the natural vegetation. Small scale commercial farms, dairies, plantations, and intensive subsistence agriculture leave 25 percent of the natural vegetation. Extensive subsistence agriculture with marginal cash crops leaves 50 percent of the natural vegetation. Rudimentary subsistence agriculture leaves 80 percent, while nomadic herding and grazing leaves 100 percent of the natural vegetation intact. Since urban areas are not the dominant land-use feature in any one cell, they are classified under cultivation.

As noted by the author, the major limitation of this analysis is that much of the data are from atlases prepared during the 1960s and 1970s. Although these data are adequate for the long-term climate analyses for which they were prepared, they do not reflect short-term changes in land use. There may have been significant changes in land use in certain ecosystems that were not taken into account in this study.

Table 4.3 Major Earthquakes, Events and Deaths, 1900–85

Source: U.S. National Oceanic and Atmospheric Administration (NOAA), World Data Center for A Solid Earth Geophysics, *Catalog of Significant Earthquakes, 2000 BC-1979*, (U.S. National Oceanic and Atmospheric Administration, Boulder, Colorado, July, 1981). Data through May 11, 1985, were provided by NOAA.

Major earthquakes include earthquakes and any associated tsunamis that caused at least ten deaths, or caused at least $1 million in damage, or had an energy of at least 7.5 on the Richter scale. (The Richter scale measures earthquakes by the logarithm of their energy. An earthquake of magnitude 8.0 has ten times the energy of an earthquake of magnitude 7.0.)

The regions are defined as follows: *Western Europe and Scandinavia:* The Scandinavian peninsula, the British Isles, and Western Europe including the Federal Republic of Germany but excluding Italy; *Southern and Eastern Europe:* Italy, the German Democratic Republic, Eastern Europe, Greece, and the Mediterranean Sea; *Africa:* All of Africa, including Madagascar; *Southwest Asia:* India, Sri Lanka, Pakistan, Iran, Iraq, Turkey, Syria, Lebanon, Jordan, Israel, and the Arabian Peninsula; *Indian Ocean:* The open Indian Ocean, excluding Madagascar and Sri Lanka; *USSR:* All of the USSR; *East Asia:* Bangladesh, Burma, China, the Korean peninsula, and Southeast Asia, *Japan and Northwest Pacific Islands:* Sakhalin, Japan, Taiwan, the Kurile, Ryukyu, and Volcano Islands, the Sea of Okhotsk, the Sea of Japan, and the Yellow Sea; *Philippines:* The Philippine archipelago; *Indonesia and Southwest Pacific Islands:* The Indonesian archipelago and the Micronesian, Polynesian, and Melanesian islands; *Australia and New Zealand:* Australia, New Zealand, and the Tasman Sea and Indian Ocean to 60° S; *Pacific Ocean:* The open ocean from 60° S to 50° N, outside of archipelagic areas under Japan, the Philippines, and Indonesia as listed above; *Southern and Western South America:* Argentina, Chile, Peru, Bolivia, Paraguay, Ecuador, and the Pacific coast of Colombia; *Brazil:* Brazil and Uruguay; *Caribbean:* All Caribbean islands, the Caribbean coast of Colombia, Guyana, Suriname, and French Guiana; *Pacific North America:* Central America and the Pacific coast of the United States and Canada; *Alaska:* Alaska, including the Aleutian Islands; *Atlantic North America:* All of North America east of the Rocky Mountains; *Atlantic Ocean:* The Atlantic Ocean, excluding the Caribbean Sea and Gulf of Mexico, and including Iceland; *Antarctica:* All land and sea south of 60° S; and *Arctic:* All land and sea north of 70° N, including Greenland.

The NOAA data base of major earthquakes has been compiled from over 100 regional and global catalogs of earthquakes and from a constant stream of incoming reports. Since reporting has been more comprehensive in developed countries than in developing countries, especially in the early part of the century, the number of major earthquakes and their death tolls may have been underreported for many developing regions.

The most catastrophic earthquakes of this century were:

Year	Country	Deaths
1908	Italy	75,000
1915	Italy	30,000
1920	China	200,000
1923	Japan	99,000
1927	China	41,000
1932	China	70,000
1939	Turkey	30,000
1970	Peru	67,000
1976	China	240,000

5. Food and Agriculture

This section provides information on agricultural production; on the changing uses of agricultural inputs such as mechanical energy, water, and fertilizer; on trends in agricultural land holdings; and on soil erosion from cropland.

Indexes of agricultural production, shown in Table 5.1, summarize changes in output over the past two decades. Globally, agricultural output has increased approximately 20 percent since the mid-1970s: it increased in 119 countries and declined in 17 countries.

Trends in yields (metric tons of crop harvested per hectare per year) are shown for two of the most important groups of crops: cereals and roots and tubers. Roots and tubers (potatoes, cassava, yams, taro, sweet potatoes) are an important source of food and fiber in many tropical and subtropical countries. Over one third of Burundi's calorie supply, for example, is from roots and tubers. Their yield, however, has not increased over the 20-year period, but the population has grown almost 50 percent. Of the 49 African countries shown in Table 5.1, only 10 show a yield increase of greater than 30 percent since 1964–66.

The increased use of chemical fertilizers, tractors, and irrigation is responsible for much of the growth in yields. As Table 5.2 shows, the use of such inputs varies greatly by continent: Africa and South America use fewer inputs than do the Soviet Union, Asia, and North America. Europe is the largest user. For example, fertilizer use per hectare was less than 1 kilogram in the Central African Republic, 19 kilograms in Zambia, 115 kilograms in Costa Rica, and 754 kilograms in the Netherlands.

Table 5.3 shows three indicators of food production: an index of total production, an index of production per capita, and the number of food calories produced domestically as a percentage of calories consumed. Asia and Europe had the highest per capita gain since the mid-1970s, registering increases of over 10 percent. North and South America and Oceania had increases of 3 to 7 percent; the Soviet Union's per capita food production index was unchanged. Africa, although registering a 15 percent increase in gross food production, had a 10 percent decline in per capita food production.

One of the most important questions asked in recent years is whether a country is becoming more or less self-sufficient in food. If a country is becoming less self-sufficent, does it have the income to purchase food on the world market, or is it becoming more dependent on food aid? Of the 28 African countries that had a calorie surplus in the late 1960s, 18 had fallen into a deficit position by the late 1970s. Only 4 of the 28 (Ivory Coast, South Africa, Swaziland, and Zimbabwe) were able to increase their surpluses, usually by only a few percent. Canada, Argentina, Thailand, the United States, and Australia increased their food surpluses.

Land distribution data, summarized in Table 5.4, indicate the extent to which holdings are becoming more or less concentrated. For example, in France in 1960, 65 percent of the holdings (occupying 67 percent of the agricultural area) were 5–50 hectares in size; in 1980, 60 percent of the holdings (54 percent of the area) were 5–50 hectares. During the same period, holdings larger than 50 hectares increased from 6 to 12 percent of all holdings, and increased in area from 29 to 42 percent of the total. Note that the three size-classes in the table may hide important differences. In Bangladesh in 1977, for example, 54 percent of the agricultural holdings were under 1 hectare and only 9 percent were larger than 3 hectares.

One of the most serious problems in maintaining good cropland is the loss of topsoil. In Table 5.5 data from a number of studies of cropland erosion, carried out in the 1970s and 1980s, indicate the presence of severe soil erosion in many parts of the world. Although there is no single standard with which to judge the severity of erosion, rates in excess of 0.5 to 2.0 metric tons per hectare per year can affect crop productivity. However, the degree of impact varies greatly depending on the depth of topsoil in a particular area.

Table 5.1 AGRICULTURAL PRODUCTION, 1964–84

	Index of Agricultural Production (1974-76 = 100)				Crop Yields (kilograms per hectare)					
	Total		Per Agricultural Worker		Cereals			Roots and Tubers		
	1964-66	1982-84	1964-66	1982-84	1964-66	1974-76	1982-84	1964-66	1974-76	1982-84
WORLD		**119**				**1953**	**2373**		**11579**	**12167**
AFRICA		**114**				**1005**	**942**		**6874**	**7002**
Algeria	70	102	73	104	513	682	599	7301	7340	6506
Angola	95	82	105	73	877	756	479	11589	13178	14045
Benin	81	121	87	112	538	721	678	6155	7654	7347
Botswana	80	86	95	80	317	599	229	4000	4641	5385
Burkina Faso	89	116	96	106	518	533	521	3352	4688	4444
Burundi	85	110	91	117	984	1134	1045	7778	6988	7115
Cameroon	66	103	75	94	1122	1017	917	3936	3516	2407
Cape Verde	150	X	177	100	691	448	454	6604	4244	3565
Central African Rep	76	108	84	98	753	518	549	3565	3231	3283
Chad	100	110	112	101	614	573	539	4562	4048	4456
Comoros	80	X	96	95	1308	1108	1118	3402	3451	3368
Congo	86	117	84	118	1125	665	566	4946	5668	6524
Djibouti	X	X	X	X	X	X	X	X	X	X
Egypt	82	111	93	102	3712	3921	4327	17311	17805	17307
Equatorial Guinea	X	X	X	X	X	X	X	3565	2736	2451
Ethiopia	92	122	107	112	775	966	1210	3046	3259	3144
Gabon	105	116	106	114	1570	1459	1520	6383	5866	6634
Gambia	84	89	95	86	1050	936	1003	4667	3274	3000
Ghana	74	87	78	79	892	873	636	8334	6136	6696
Guinea	78	109	86	100	811	832	878	7463	7115	7293
Guinea-Bissau	97	117	107	100	720	730	752	6154	4872	6154
Ivory Coast	66	136	88	113	800	813	904	3698	4145	3972
Kenya	68	123	91	100	1228	1564	1472	7363	7807	7900
Lesotho	86	91	98	90	780	772	544	14667	12951	15000
Liberia	67	112	77	99	698	1220	1158	4164	3886	3908
Libya	45	125	34	186	299	449	455	4535	5071	7644
Madagascar	75	110	88	100	1712	1805	1685	6361	6118	5899
Malawi	69	131	83	114	946	1057	1164	4838	3892	3997
Mali	85	131	98	116	784	779	742	8218	9041	9463
Mauritania	122	119	146	103	362	414	274	2511	1119	1871
Mauritius	91	104	95	94	1723	2589	2514	12318	15686	20009
Morocco	78	115	86	95	739	1049	910	10446	11449	13860
Mozambique	83	98	96	87	929	719	646	4822	4891	5852
Niger	108	141	128	123	522	395	372	8120	6620	6949
Nigeria	86	125	98	116	669	662	675	7910	10062	10005
Rwanda	59	143	76	120	1295	1037	1279	5674	8299	9137
Senegal	80	87	98	76	569	720	616	4250	3049	3485
Sierra Leone	84	108	84	109	1323	1428	1371	3624	4306	3330
Somalia	85	113	99	75	493	636	611	10000	10800	10841
South Africa	72	101	88	97	947	1403	1178	8292	12039	11663
Sudan	70	106	83	106	696	645	470	3457	3604	3500
Swaziland	56	146	61	134	471	1484	1294	3828	3777	2446
Tanzania, United Rep	79	116	99	98	789	980	964	5288	7027	10716
Togo	89	114	108	105	474	939	924	11919	13024	11231
Tunisia	68	105	65	105	691	824	827	8217	9500	13093
Uganda	53	117	67	92	901	1216	1620	4657	3729	3805
Zaire	79	121	90	107	688	745	821	6741	6882	6876
Zambia	60	96	70	86	846	1217	1637	3261	3378	3635
Zimbabwe	63	99	76	87	896	1446	936	4033	3985	4514
NORTH AMERICA		**115**				**2895**	**3458**		**18127**	**18795**
Barbados	123	110	106	113	1910	2614	2500	8766	10659	13052
Canada	89	129	69	165	1743	2027	2245	18504	21501	23478
Costa Rica	60	113	71	100	1384	1735	1873	7350	8360	5690
Cuba	73	137	63	156	1178	2034	2779	5397	5435	6129
Dominican Rep	70	115	82	107	2081	2696	3112	6282	6073	6080
El Salvador	72	104	89	89	1179	1543	1709	7729	11724	13196
Guatemala	65	114	79	102	925	1459	1484	3821	3851	4526
Haiti	84	108	89	101	1068	1176	1034	4223	4320	4019
Honduras	76	143	93	115	1166	1093	1363	5356	3468	5287
Jamaica	88	98	69	112	1179	1763	1703	9234	10207	18127
Mexico	75	126	82	129	1309	1698	2208	8576	12070	13064
Nicaragua	68	94	75	87	1030	1045	1793	4133	4068	4039
Panama	73	120	81	117	960	1194	1481	8250	8230	7374
Trinidad and Tobago	82	67	87	78	2425	2859	3321	8913	11812	11775
United States	83	113	54	149	2901	3339	4098	21468	27227	29525
SOUTH AMERICA		**126**				**1641**	**1959**		**10968**	**10824**
Argentina	78	121	73	129	1552	1971	2420	10002	13278	15561
Bolivia	62	100	71	92	953	1150	1212	5502	6975	5049
Brazil	70	135	77	130	1335	1420	1604	13054	12006	11174
Chile	89	117	83	119	1756	1679	2390	9287	9793	11206
Colombia	71	125	65	135	1338	2367	2533	7592	9243	11104
Ecuador	80	113	94	97	912	1352	1855	8224	10749	10109
Guyana	84	105	80	99	2031	2139	3191	6051	6604	6734
Paraguay	75	135	93	117	1263	1400	1269	13515	14144	14045
Peru	85	103	92	96	1551	1830	2674	6664	7007	7903
Suriname	64	140	49	168	3072	3630	3946	7058	5860	5000
Uruguay	90	112	70	125	969	1282	1917	4835	5250	5607
Venezuela	66	114	67	127	1250	1548	1982	8631	7647	8483

Table 5.1

	Index of Agricultural Production (1974-76 = 100)				Crop Yields (kilograms per hectare)					
	Total		Per Agricultural Worker		Cereals			Roots and Tubers		
	1964-66	1982-84	1964-66	1982-84	1964-66	1974-76	1982-84	1964-66	1974-76	1982-84
ASIA		**130**				**1822**	**2395**		**12049**	**13938**
Afghanistan	80	103	92	108	1065	1297	1333	10000	13727	13700
Bahrain	X	X	X	X	X	X	X	20000	29000	20953
Bangladesh	90	125	114	102	1645	1771	2033	8206	9945	10463
Bhutan	79	122	93	107	1419	1424	1413	6511	6602	6802
Burma	80	151	81	145	1525	1736	2932	3392	5628	8972
China	72	145	81	149	1750	2479	3698	9211	12904	15552
Cyprus	75	118	73	128	1059	1396	1626	15464	19842	21770
India	76	130	84	123	904	1179	1486	8841	12063	13775
Indonesia	70	141	76	137	1529	2338	3352	6976	8360	9315
Iran	63	123	72	118	873	1057	1107	17944	17273	14921
Iraq	78	117	90	114	779	854	736	10000	9019	19207
Israel	59	125	55	143	1650	2112	2205	23247	30599	45402
Japan	92	96	60	158	4409	5620	5521	18461	21297	23800
Jordan	171	172	166	191	1020	643	654	8826	11743	18564
Kampuchea Dem	146	98	152	117	1118	1306	935	10132	8403	7720
Korea Dem People's Rep	62	137	70	131	2864	3590	4105	10519	12191	12524
Korea Rep	69	122	69	143	3031	4140	5356	16996	16953	19319
Kuwait	X	X	X	X	X	2000	3262	X	10500	15000
Lao People's Dem Rep	85	158	95	142	818	1312	1686	7492	9939	11547
Lebanon	90	132	54	248	951	1222	1211	11786	6979	14909
Malaysia	55	127	63	121	2087	2724	2647	9403	10506	10073
Mongolia	87	112	92	114	778	904	1147	7952	7655	10953
Nepal	83	110	102	96	1831	1755	1616	5717	5648	5128
Oman	X	X	X	X	3	1273	1754	X	X	3555
Pakistan	70	133	81	117	871	1389	1637	9225	10768	10302
Philippines	65	134	68	127	1048	1303	1723	5596	5293	6516
Qatar	X	X	X	X	X	3568	3711	X	10600	10000
Saudi Arabia	56	136	75	196	1324	737	1942	8775	5045	7500
Singapore	49	94	33	130	X	X	X	5762	6217	5865
Sri Lanka	82	127	97	111	1777	1825	2903	6196	4435	11080
Syrian Arab Rep	67	158	85	127	780	950	777	X	13047	15674
Thailand	67	136	80	125	1819	1882	1986	13042	14261	16394
Turkey	73	121	71	130	1176	1579	1925	11657	13870	16664
United Arab Emirates	X	X	X	X	X	X	2491	X	15533	14575
Viet Nam	87	148	94	137	1906	2127	2523	5820	6461	5307
Yemen	87	103	94	95	744	817	865	6184	10990	12368
Yemen Dem	75	99	81	95	1228	1651	1549	5004	11364	10547
EUROPE		**115**				**3178**	**3989**		**18346**	**18770**
Albania	74	128	87	115	1126	2112	2974	7842	7032	8029
Austria	84	115	51	163	2631	4000	4881	20469	23679	25636
Belgium	79	103	49	147	3613	4203	5542	30808	33463	35909
Bulgaria	82	115	67	155	2455	3460	4181	10840	11201	10613
Czechoslovakia	75	122	50	169	2202	3578	4403	15148	16026	18471
Denmark	100	127	67	171	3856	3705	4609	23382	22497	32935
Finland	87	103	54	153	1790	2592	3054	15002	14477	17054
France	87	115	57	156	2946	3776	5312	18671	20906	29555
German Dem Rep	80	106	59	131	2745	3575	4124	17829	15419	16438
Germany Fed Rep	88	115	46	176	3044	3973	4880	24353	27133	28874
Greece	70	113	58	124	1705	2493	3300	9428	15003	16742
Hungary	73	126	49	189	2278	3806	5031	9106	12416	16497
Ireland	77	111	63	127	3104	3929	5466	22934	25666	27303
Italy	86	114	52	166	2347	3282	3667	10722	16551	17806
Luxembourg	X	X	X	X	X	X	X	X	X	X
Malta	69	141	58	127	1532	2089	3724	6318	8784	6985
Netherlands	69	125	55	166	3861	4771	6752	30147	35141	37460
Norway	92	120	59	160	2439	3052	3753	21437	22958	24091
Poland	79	101	74	105	1797	2673	2777	16411	18743	15880
Portugal	87	90	68	123	825	1118	1115	9360	8764	8416
Romania	67	126	62	145	1853	2628	3628	8610	12685	18418
Spain	68	115	45	152	1252	1834	2139	11533	14088	15933
Sweden	94	115	58	166	2979	3665	4036	23719	23499	27110
Switzerland	83	115	63	153	3382	4521	5481	25600	35544	36733
United Kingdom	91	124	64	157	3677	3930	5795	24080	25664	34346
Yugoslavia	77	118	66	144	2297	3292	4043	8263	8859	9321
USSR	**77**	**106**	**51**	**141**	**1158**	**1466**	**1509**	**10586**	**11088**	**11986**
OCEANIA		**115**				**1420**	**1404**		**9906**	**10382**
Australia	83	114	74	136	1247	1384	1364	14973	19785	23891
Fiji	94	135	112	124	1738	2184	2061	8930	9463	9206
New Zealand	84	116	81	134	3376	3494	4751	20690	25365	25264
Papua New Guinea	76	123	90	106	2218	1871	1349	6793	6936	6973
Solomon Islands	86	166	98	142	2095	1995	3498	12796	13146	14992
ANTARCTICA										

Source: U.N. Food and Agriculture Organization.
X = not available.
For additional information, see Sources and Technical Notes.

Table 5.2 AGRICULTURAL INPUTS, 1964–83

	Arable and Permanent Cropland (thousand hectares)			Irrigated Land as Percentage of Arable and Permanent Cropland		Fertilizer Use (kilograms of plant nutrient per hectare of arable and permanent cropland)			Tractors (number per thousand hectares of arable and permanent cropland)		
	1964–66	1974–76	1981–83	1974–76	1981–83	1964–66	1974–76	1981–83	1964–66	1974–76	1981–83
WORLD		**1435183**	**1469846**	**13**	**14**		**60**	**78**		**12.8**	**15.3**
AFRICA		**176027**	**182821**	**4**	**4**		**13**	**19**		**2.2**	**2.7**
Algeria	6774	7469	7510	4	5	7	20	19	4.3	5.5	8.6
Angola	3313	3500	3500	0	0	1	3	2	1.0	2.6	2.9
Benin	1439	1762	1802	1	1	1	2	2	0.1	0.0	0.1
Botswana	1027	1330	1360	0	0	2	2	1	1.1	1.4	1.6
Burkina Faso	2179	2509	2633	0	0	0	0	4	0.0	0.0	0.0
Burundi	988	1255	1306	0	0	0	1	1	0.0	0.0	0.0
Cameroon	5740	6395	6950	0	0	2	2	6	0.0	0.0	0.1
Cape Verde	40	40	40	5	5	X	0	0	0.2	0.7	0.8
Central African Rep	1780	1887	1958	0	0	0	1	0	0.0	0.1	0.1
Chad	2900	3007	3152	0	0	0	2	2	0.0	0.0	0.1
Comoros	85	90	92	0	0	X	0	0	X	0.0	0.0
Congo	624	652	672	0	0	3	5	2	0.6	1.0	1.0
Djibouti	X	0	0	0	0	X	0	0	X	0.0	0.0
Egypt	2653	2799	2469	100	100	117	166	311	5.5	8.7	16.2
Equatorial Guinea	222	230	230	0	0	3	0	0	0.2	0.4	0.4
Ethiopia	12442	13730	13953	0	0	0	2	3	0.1	0.3	0.3
Gabon	205	374	452	0	0	X	0	2	1.6	2.2	2.9
Gambia	125	151	159	17	21	3	7	12	0.4	0.3	0.3
Ghana	2627	2700	2767	1	1	0	6	10	0.8	1.2	1.3
Guinea	1570	1570	1574	0	1	2	1	2	0.0	0.1	0.1
Guinea-Bissau	263	285	287	0	0	X	0	4	0.1	0.1	0.2
Ivory Coast	2670	3483	3962	1	1	4	10	10	0.3	0.5	0.8
Kenya	1890	2240	2336	2	2	13	22	32	3.1	2.6	2.8
Lesotho	357	361	298	0	0	2	4	15	0.6	3.6	5.0
Liberia	372	366	371	1	1	2	11	9	0.3	0.7	0.8
Libya	1997	2054	2091	10	11	3	14	38	1.6	6.3	12.4
Madagascar	2245	2666	3004	16	16	2	3	4	0.8	0.8	0.9
Malawi	1987	2273	2332	0	0	2	6	14	0.2	0.4	0.5
Mali	1688	1900	2055	5	5	1	2	5	0.2	0.4	0.4
Mauritania	273	188	199	4	4	0	3	0	0.1	1.0	1.6
Mauritius	93	106	107	14	15	245	241	224	3.0	2.8	3.1
Morocco	7223	7699	8401	6	6	7	21	26	1.1	2.4	2.9
Mozambique	2687	3080	3080	2	2	2	2	13	1.0	1.8	1.9
Niger	2260	2497	3590	1	1	0	0	1	0.0	0.0	0.0
Nigeria	29197	30000	30418	0	0	0	1	7	0.0	0.2	0.3
Rwanda	655	912	1018	0	0	X	0	1	0.1	0.1	0.1
Senegal	4500	5000	5226	3	3	3	9	4	0.1	0.1	0.1
Sierra Leone	1435	1603	1769	0	0	0	1	1	0.1	0.1	0.2
Somalia	981	1055	1083	16	15	1	3	1	0.8	1.2	1.5
South Africa	13055	13393	13620	8	8	29	56	87	10.6	12.9	13.3
Sudan	11200	12160	12448	13	14	2	6	6	0.2	0.7	0.9
Swaziland	143	164	139	16	22	35	55	129	5.4	14.9	20.7
Tanzania, United Rep	3797	5030	5193	1	1	2	6	5	4.6	3.5	3.6
Togo	1123	1415	1426	0	1	0	1	2	0.0	0.1	0.2
Tunisia	4334	4860	4786	3	4	5	10	17	3.3	5.0	5.5
Uganda	4876	5403	5967	0	0	1	1	0	0.1	0.3	0.5
Zaire	5670	6117	6406	0	0	0	1	1	0.2	0.2	0.3
Zambia	4860	4998	5158	0	0	2	12	19	0.3	0.8	0.9
Zimbabwe	2118	2524	2714	3	4	35	60	60	6.9	7.0	7.5
NORTH AMERICA		**267067**	**273206**	**9**	**10**		**77**	**83**		**21.7**	**20.2**
Barbados	33	33	33	0	0	211	167	182	10.5	14.5	17.2
Canada	41550	43363	46194	1	1	17	29	43	14.1	13.5	14.2
Costa Rica	485	508	629	5	4	59	137	115	9.5	8.9	9.6
Cuba	1846	3087	3213	19	31	134	103	181	11.9	16.2	20.6
Dominican Rep	1050	1263	1445	11	12	12	68	38	2.1	1.9	2.2
El Salvador	658	657	725	5	15	71	147	102	2.7	4.0	4.6
Guatemala	1544	1648	1785	4	4	14	36	50	1.7	2.1	2.3
Haiti	730	860	897	8	8	0	2	6	0.4	0.5	0.6
Honduras	1507	1634	1768	5	6	6	12	15	0.3	1.6	1.9
Jamaica	287	262	267	12	12	62	84	64	13.7	9.3	10.9
Mexico	23482	23200	23500	20	22	15	42	72	3.1	4.2	6.7
Nicaragua	1192	1230	1260	5	6	17	22	33	0.2	0.8	1.8
Panama	558	559	582	4	5	17	47	49	2.2	0.3	7.0
Trinidad and Tobago	139	157	158	12	13	56	51	35	11.8	13.3	15.6
United States	178754	188218	190388	9	11	63	93	94	28.1	26.9	24.2
SOUTH AMERICA		**121659**	**138121**	**5**	**6**		**22**	**27**		**4.2**	**4.9**
Argentina	29286	34650	35567	4	5	1	2	3	5.3	5.1	4.3
Bolivia	1640	3264	3375	4	4	1	1	1	0.2	0.2	0.2
Brazil	51390	60672	74213	2	3	5	31	37	2.3	3.4	4.6
Chile	4427	5260	5528	24	23	26	25	20	7.6	6.2	6.3
Colombia	5053	5318	5673	5	6	28	44	53	4.1	4.3	5.0
Ecuador	2527	2583	2550	20	21	6	14	28	0.8	2.0	2.0
Guyana	362	388	495	31	25	23	37	25	9.1	6.8	7.1
Paraguay	903	1233	1940	4	3	2	1	4	1.9	1.6	4.1
Peru	2648	3222	3516	35	34	29	38	32	3.2	3.5	4.7
Suriname	38	45	57	67	68	33	89	120	20.0	21.6	40.9
Uruguay	1406	1439	1448	4	6	29	40	41	17.6	20.6	23.2
Venezuela	3484	3582	3756	8	8	10	38	40	4.4	7.4	10.7

Table 5.2

	Arable and Permanent Cropland (thousand hectares)			Irrigated Land as Percentage of Arable and Permanent Cropland		Fertilizer Use (kilograms of plant nutrient per hectare of arable and permanent cropland)			Tractors (number per thousand hectares of arable and permanent cropland)		
	1964-66	1974-76	1981-83	1974-76	1981-83	1964-66	1974-76	1981-83	1964-66	1974-76	1981-83
ASIA		**452035**	**455838**	**27**	**29**		**35**	**71**		**4.2**	**8.5**
Afghanistan	7887	8048	8054	31	33	0	4	6	0.0	0.1	0.1
Bahrain	2	2	2	50	50	X	0	104	X	0.0	0.0
Bangladesh	9002	9129	9134	15	20	6	19	48	0.1	0.3	0.5
Bhutan	69	84	96	0	0	X	0	1	X	0.0	0.0
Burma	10295	9985	10071	10	10	1	5	15	0.3	0.8	0.9
China	103533	101075	100895	42	45	24	61	155	0.8	4.4	8.1
Cyprus	432	432	432	22	22	38	46	41	11.5	22.6	25.5
India	162424	167810	168760	20	23	5	15	34	0.3	1.3	2.7
Indonesia	17380	19516	19820	25	27	6	25	75	0.4	0.5	0.7
Iran	15453	16450	13700	36	30	3	20	57	0.9	3.2	5.5
Iraq	4903	5287	5450	30	32	1	6	14	1.3	3.6	5.3
Israel	407	420	425	43	49	96	167	179	26.3	47.0	63.4
Japan	5868	5092	4829	64	67	333	378	400	9.9	145.2	312.2
Jordan	349	391	413	9	9	12	14	26	5.4	9.1	11.9
Kampuchea, Dem	2900	3046	3046	3	3	1	0	5	0.3	0.4	0.4
Korea, Dem People's Rep	1931	2140	2272	42	47	90	199	336	6.8	11.0	24.6
Korea, Rep	2240	2239	2178	47	54	167	383	317	0.0	0.3	2.6
Kuwait	1	1	2	100	60	X	0	370	3.0	10.2	15.2
Lao People's Dem Rep	833	848	888	5	13	1	0	2	0.1	0.4	0.8
Lebanon	291	335	298	26	29	69	82	134	6.5	10.1	10.1
Malaysia	3700	4199	4337	7	8	27	56	97	0.7	1.3	1.8
Mongolia	834	859	1259	3	3	X	5	11	5.0	6.3	8.3
Nepal	1831	2326	2331	8	10	1	5	12	0.2	0.2	0.2
Oman	26	37	42	92	94	X	0	33	0.3	1.6	2.6
Pakistan	19234	19715	20372	69	72	5	25	57	0.4	1.9	6.0
Philippines	9210	9832	11387	11	12	11	26	29	0.6	1.1	1.6
Qatar	1	2	3	0	0	X	0	277	13.0	12.7	24.8
Saudi Arabia	767	1108	1131	34	35	8	8	72	0.3	0.7	1.2
Singapore	13	8	6	0	0	185	375	742	0.6	5.2	7.6
Sri Lanka	1875	2066	2172	23	25	51	42	70	4.1	7.2	11.8
Syrian Arab Rep	6461	5725	5722	10	10	3	9	25	1.2	2.7	6.1
Thailand	12607	16677	19009	14	18	3	11	19	0.3	1.3	5.4
Turkey	26207	27764	27395	7	8	6	25	50	2.1	8.8	17.8
United Arab Emirates	9	12	14	42	36	X	83	283	X	0.0	0.0
Viet Nam	5985	6273	6779	17	25	12	49	38	0.5	1.1	5.6
Yemen	2697	2785	2790	8	9	0	1	5	0.1	0.4	0.8
Yemen, Dem	174	195	209	29	31	X	3	10-	3.7	4.5	5.1
EUROPE		**142138**	**140532**	**9**	**11**		**196**	**223**		**51.2**	**63.1**
Albania	521	668	708	49	54	15	95	135	8.5	13.2	15.3
Austria	1713	1613	1600	0	0	180	202	234	112.1	181.0	201.8
Belgium	1000	894	831	0	0	466	544	505	68.6	127.1	137.6
Bulgaria	4567	4386	4152	26	29	82	142	251	9.2	15.4	14.3
Czechoslovakia	5262	5268	5170	3	3	167	307	335	23.4	27.1	25.8
Denmark	2716	2661	2647	7	15	183	228	240	59.4	70.1	68.9
Finland	2526	2481	2364	2	3	135	223	209	50.1	78.2	95.6
France	20528	18859	18655	4	6	155	248	299	48.7	72.8	82.0
German Dem Rep	5009	4942	5006	3	3	257	371	313	24.9	27.9	30.0
Germany, Fed Rep	7639	7576	7465	4	4	367	419	427	152.1	191.6	196.7
Greece	3851	3873	3953	23	25	66	115	148	10.2	23.6	40.1
Hungary	5634	5490	5303	5	3	64	260	284	11.2	11.7	10.4
Ireland	1252	1006	972	0	0	197	394	622	47.7	116.7	149.9
Italy	15311	12318	12354	22	24	68	112	164	27.4	66.5	92.1
Luxembourg	X	X	X	X	X	X	X	X	X	X	X
Malta	14	13	14	8	7	30	0	25	6.6	23.6	31.4
Netherlands	964	841	862	51	49	582	757	754	97.5	181.8	214.6
Norway	849	793	841	5	9	196	291	309	84.8	125.7	166.4
Poland	[illegible]	15067	14826	1	1	84	237	220	7.9	27.0	48.0
Portugal	[illegible]	3620	3550	17	18	40	63	75	3.8	12.8	21.4
Romania	10491	10496	10531	15	23	25	101	144	7.9	11.5	15.6
Spain	X	20792	20496	14	15	X	70	70	X	18.5	27.8
Sweden	3179	3009	2979	2	2	121	168	162	53.9	62.8	63.7
Switzerland	403	393	411	6	6	324	368	413	159.4	200.1	248.6
United Kingdom	5449	7028	6987	1	2	288	249	347	87.0	69.3	74.7
Yugoslavia	8305	8035	7839	2	2	57	67	124	6.1	28.8	62.7
USSR	**229350**	**232406**	**232276**	**6**	**8**	**X**	**69**	**85**	**X**	**10.0**	**11.4**
OCEANIA		**43850**	**47051**	**4**	**4**		**30**	**35**		**9.1**	**9.2**
Australia	37503	42315	45433	3	4	28	19	25	8.1	7.3	7.3
Fiji	206	230	236	0	0	32	52	69	5.5	6.0	6.8
New Zealand	487	411	464	36	43	908	1187	1014	186.2	201.7	207.2
Papua New Guinea	310	351	371	0	0	1	19	24	3.8	3.2	4.0
Solomon Islands	50	50	53	0	0	X	0	0	X	0.0	0.0
ANTARCTICA											

Source: U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 5.3 FOOD PRODUCTION AND CONSUMPTION, 1964–84

	Index of Food Production (1974–76 = 100)				Calories Domestically Produced as Percentage of Total Supply	
	Total		Per Capita			
	1964–66	1982–84	1964–66	1982–84	1967–70	1977–80
WORLD		**119**		**104**	**101**	**101**
AFRICA		**115**		**90**	**102**	**93**
Algeria	70	101	95	79	85	58
Angola	86	103	109	81	109	86
Benin	82	120	100	97	110	100
Botswana	80	86	116	64	68	52
Burkina Faso	90	114	108	96	102	95
Burundi	86	108	101	92	99	98
Cameroon	65	101	82	83	104	98
Cape Verde	149	X	188	X	58	46
Central African Rep	76	111	91	94	98	99
Chad	103	114	124	96	98	100
Comoros	81	X	108	X	93	86
Congo	86	117	108	96	113	89
Djibouti	X	X	X	X	X	X
Egypt	77	112	96	91	91	79
Equatorial Guinea	X	X	X	X	X	X
Ethiopia	92	121	118	102	101	97
Gabon	104	116	116	103	90	72
Gambia	84	89	105	76	127	112
Ghana	75	87	97	68	106	98
Guinea	78	109	96	91	100	93
Guinea-Bissau	100	117	119	86	105	88
Ivory Coast	60	148	90	109	104	106
Kenya	70	117	101	85	102	97
Lesotho	81	89	96	73	84	73
Liberia	67	116	89	90	93	87
Libya	45	126	74	92	54	45
Madagascar	74	112	93	90	103	98
Malawi	72	127	93	100	105	104
Mali	87	129	108	107	99	96
Mauritania	122	119	158	95	81	54
Mauritius	91	103	103	89	178	158
Morocco	78	116	106	91	98	79
Mozambique	80	100	108	73	110	97
Niger	108	141	138	115	111	104
Nigeria	86	126	117	96	105	93
Rwanda	59	145	81	111	99	98
Senegal	81	86	115	67	112	95
Sierra Leone	84	108	97	95	101	96
Somalia	85	113	108	68	94	80
South Africa	69	101	87	83	115	116
Sudan	71	108	93	85	103	100
Swaziland	58	144	75	114	147	151
Tanzania, United Rep	71	126	99	96	101	98
Togo	88	113	121	92	104	95
Tunisia	69	104	84	85	81	76
Uganda	80	119	84	91	102	98
Zaire	80	121	101	96	102	96
Zambia	58	94	79	73	92	89
Zimbabwe	55	90	76	69	113	114
NORTH AMERICA		**117**		**104**	**116**	**130**
Barbados	123	110	135	103	158	118
Canada	89	129	105	118	131	143
Costa Rica	57	104	76	83	109	109
Cuba	73	138	90	130	148	139
Dominican Rep	69	117	94	97	135	121
El Salvador	69	112	92	89	97	97
Guatemala	63	126	87	100	101	104
Haiti	82	109	99	90	98	87
Honduras	74	138	101	104	113	104
Jamaica	88	98	108	88	115	81
Mexico	70	130	102	104	105	94
Nicaragua	64	99	88	78	110	107
Panama	72	118	93	99	106	109
Trinidad and Tobago	81	67	104	66	104	76
United States	82	114	87	105	115	134
SOUTH AMERICA		**128**		**107**	**107**	**108**
Argentina	77	123	91	108	139	153
Bolivia	64	103	81	83	88	93
Brazil	64	139	81	116	102	105
Chile	88	116	108	101	88	82
Colombia	68	123	90	104	99	96
Ecuador	81	114	107	89	108	99
Guyana	83	104	102	89	148	135
Paraguay	79	136	101	105	99	112
Peru	80	103	106	83	96	87
Suriname	64	140	75	146	100	105
Uruguay	85	110	89	105	101	103
Venezuela	65	116	99	88	84	70

Table 5.3

	Index of Food Production (1974–76 = 100)				Calories Domestically Produced as Percentage of Total Supply	
	Total		Per Capita			
	1964–66	1982–84	1964–66	1982–84	1967–70	1977–80
ASIA		**130**		**112**	**98**	**96**
Afghanistan	82	108	99	106	98	98
Bahrain	X	X	X	X	X	X
Bangladesh	88	125	115	100	96	95
Bhutan	79	122	96	104	84	84
Burma	80	152	104	124	105	105
China	72	141	93	126	100	98
Cyprus	74	118	83	111	86	59
India	75	131	94	110	100	100
Indonesia	69	142	87	121	100	99
Iran	62	125	87	98	96	81
Iraq	78	118	107	89	92	66
Israel	61	119	79	100	54	49
Japan	91	97	106	91	73	61
Jordan	172	172	228	137	63	38
Kampuchea, Dem	141	99	162	98	112	93
Korea, Dem People's Rep	61	137	79	113	96	98
Korea, Rep	70	125	88	111	89	78
Kuwait	X	X	X	X	X	X
Lao People's Dem Rep	84	158	108	129	96	93
Lebanon	90	137	117	142	55	47
Malaysia	54	134	71	111	93	132
Mongolia	85	114	119	91	92	87
Nepal	82	110	104	91	105	99
Oman	X	X	X	X	X	X
Pakistan	69	133	90	104	100	98
Philippines	65	132	86	108	114	112
Qatar	X	X	X	X	X	X
Saudi Arabia	56	135	84	94	67	34
Singapore	50	94	44	86	36	39
Sri Lanka	69	140	84	121	82	83
Syrian Arab Rep	62	163	88	124	93	93
Thailand	66	136	90	113	118	133
Turkey	73	123	92	104	100	103
United Arab Emirates	X	X	X	X	X	X
Viet Nam	87	148	111	123	89	93
Yemen	37	104	103	88	94	80
Yemen, Dem	74	100	91	82	57	60
EUROPE		**115**		**111**	**91**	**92**
Albania	70	128	91	106	94	100
Austria	84	115	86	115	92	95
Belgium	79	104	87	103	75	75
Bulgaria	81	121	90	119	102	96
Czechoslovakia	74	122	82	117	90	94
Denmark	100	127	104	126	103	108
Finland	87	103	87	100	97	98
France	87	115	93	111	112	118
German Dem Rep	79	106	76	107	88	84
Germany, Fed Rep	88	115	90	116	83	86
Greece	69	113	76	104	98	95
Hungary	72	127	75	125	101	107
Ireland	77	111	78	101	96	100
Italy	86	114	91	111	83	82
Luxembourg	X	X	X	X	X	X
Malta	69	144	75	132	34	30
Netherlands	68	125	77	119	80	76
Norway	92	120	94	116	81	81
Poland	78	101	88	94	97	86
Portugal	86	89	99	85	83	57
Romania	67	126	77	119	105	100
Spain	65	115	77	107	90	89
Sweden	94	115	89	113	101	104
Switzerland	83	116	89	114	63	66
United Kingdom	91	124	88	124	70	79
Yugoslavia	76	119	82	111	101	96
USSR	**76**	**107**	**85**	**100**	**100**	**92**
OCEANIA		**117**		**103**	**159**	**174**
Australia	78	117	90	104	170	192
Fiji	95	136	121	118	169	153
New Zealand	80	114	89	110	129	130
Papua New Guinea	79	122	102	96	115	112
Solomon Islands	86	166	117	124	136	161
ANTARCTICA						

Source: U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 5.4 LAND DISTRIBUTION, 1960-80

	Agricultural Holdings: Distribution by Size of Holdings (percent)									Agricultural Area: Distribution by Size of Holdings (percent)								
	1960			1970			1980			1960			1970			1980		
	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha
WORLD																		
AFRICA																		
Algeria	X	X	X	69	30	1	X	X	X	X	X	X	14	63	23	X	X	X
Angola	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Benin	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Botswana	X	X	X	74	26	0	X	X	X	X	X	X	26	74	0	X	X	X
Burkina Faso	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Burundi	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cameroon	X	X	X	97	4	0	X	X	X	X	X	X	84	16	0	X	X	X
Cape Verde	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Central African Rep	X	X	X	98	3	0	X	X	X	X	X	X	90	10	0	X	X	X
Chad	X	X	X	89	11	0	X	X	X	X	X	X	72	28	0	X	X	X
Comoros	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Congo	X	X	X	99	1	0	X	X	X	X	X	X	98	2	0	X	X	X
Djibouti	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Egypt	90	10	0	X	X	X	X	X	X	51	34	16	X	X	X	X	X	X
Equatorial Guinea	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ethiopia	X	X	X	X	X	X	96	4	0	X	X	X	X	X	X	82	18	0
Gabon	X	X	X	100	0	0	X	X	X	X	X	X	100	0	0	X	X	X
Gambia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ghana	X	X	X	86	14	0	X	X	X	X	X	X	47	54	0	X	X	X
Guinea	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Guinea-Bissau	85	16	0	X	X	X	X	X	X	61	39	0	X	X	X	X	X	X
Ivory Coast	X	X	X	64	36	0	X	X	X	X	X	X	32	68	1	X	X	X
Kenya	74	25	1	90	10	0	X	X	X	14	21	65	38	18	43	X	X	X
Lesotho	94	6	0	96	4	0	X	X	X	77	23	0	84	16	0	X	X	X
Liberia	X	X	X	93	7	0	X	X	X	X	X	X	36	35	29	X	X	X
Libya	24	62	14	X	X	X	X	X	X	2	35	63	X	X	X	X	X	X
Madagascar	97	3	0	X	X	X	X	X	X	89	11	0	X	X	X	X	X	X
Malawi	X	X	X	100	0	0	X	X	X	X	X	X	100	0	0	X	X	X
Mali	68	32	0	X	X	X	X	X	X	37	63	0	X	X	X	X	X	X
Mauritania	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mauritius	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Morocco	75	25	0	X	X	X	X	X	X	38	62	0	X	X	X	X	X	X
Mozambique	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Niger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nigeria	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rwanda	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Senegal	72	28	0	X	X	X	X	X	X	41	59	0	X	X	X	X	X	X
Sierra Leone	X	X	X	94	6	0	X	X	X	X	X	X	80	20	0	X	X	X
Somalia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
South Africa	5	19	76	X	X	X	X	X	X	0	0	100	X	X	X	X	X	X
Sudan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Swaziland	X	X	X	87	13	0	X	X	X	X	X	X	8	6	85	X	X	X
Tanzania, United Rep	X	X	X	95	5	0	X	X	X	X	X	X	79	21	0	X	X	X
Togo	87	13	0	97	3	0	X	X	X	57	43	0	74	27	0	X	X	X
Tunisia	41	55	4	X	X	X	X	X	X	6	54	40	X	X	X	X	X	X
Uganda	75	25	0	X	X	X	X	X	X	43	57	0	X	X	X	X	X	X
Zaire	X	X	X	99	1	0	X	X	X	X	X	X	60	5	35	X	X	X
Zambia	0	14	86	94	6	0	X	X	X	0	0	100	34	19	47	X	X	X
Zimbabwe	0	9	91	X	X	X	X	X	X	0	0	100	X	X	X	X	X	X
NORTH AMERICA																		
Barbados	81	7	13	X	X	X	X	X	X	6	5	89	X	X	X	X	X	X
Canada	4	30	66	5	24	72	X	X	X	0	7	93	0	3	97	X	X	X
Costa Rica	39	48	15	49	37	15	X	X	X	2	22	76	2	18	80	X	X	X
Cuba	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dominican Rep	86	13	1	77	21	2	X	X	X	21	31	48	13	30	57	X	X	X
El Salvador	85	13	2	89	10	1	X	X	X	15	28	57	20	31	49	X	X	X
Guatemala	74	24	3	X	X	X	X	X	X	13	24	63	X	X	X	X	X	X
Haiti	X	X	X	96	4	0	X	X	X	X	X	X	78	23	0	X	X	X
Honduras	X	X	X	64	32	4	X	X	X	X	X	X	9	35	56	X	X	X
Jamaica	90	10	1	94	6	0	X	X	X	23	23	54	29	19	52	X	X	X
Mexico	66	22	12	60	26	14	X	X	X	1	3	96	1	4	96	X	X	X
Nicaragua	40	43	16	X	X	X	X	X	X	2	18	79	X	X	X	X	X	X
Panama	46	47	6	56	37	8	66	27	7	5	37	58	4	33	64	4	30	66
Trinidad and Tobago	72	27	2	X	X	X	X	X	X	20	34	46	X	X	X	X	X	X
United States	8	45	47	7	39	54	X	X	X	0	9	91	0	6	94	X	X	X
SOUTH AMERICA																		
Argentina	15	39	47	X	X	X	X	X	X	0	2	98	X	X	X	X	X	X
Bolivia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brazil	31	51	19	37	47	16	X	X	X	1	13	86	1	14	85	X	X	X
Chile	38	44	18	X	X	X	X	X	X	1	5	94	X	X	X	X	X	X
Colombia	63	31	7	60	32	8	X	X	X	5	20	76	4	19	78	X	X	X
Ecuador	X	X	X	67	27	7	X	X	X	X	X	X	7	28	65	X	X	X
Guyana	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Paraguay	44	51	6	X	X	X	X	X	X	1	7	92	X	X	X	X	X	X
Peru	84	14	2	78	20	2	X	X	X	6	8	86	7	14	79	X	X	X
Suriname	81	19	0	81	19	0	X	X	X	24	27	49	28	28	45	X	X	X
Uruguay	15	50	36	14	48	38	12	46	42	0	5	95	0	4	96	0	4	96
Venezuela	50	40	10	44	43	14	X	X	X	1	7	92	1	7	93	X	X	X

Table 5.4

	Agricultural Holdings: Distribution by Size of Holdings (percent)									Agricultural Area: Distribution by Size of Holdings (percent)								
	1960			1970			1980			1960			1970			1980		
	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha	less than 5 ha	5-50 ha	more than 50 ha
ASIA																		
Afghanistan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bahrain	X	X	X	100	0	0	72	28	0	X	X	X	35	63	3	33	62	83
Bangladesh	X	X	X	X	X	X	100	0	0	X	X	X	X	X	X	100	0	0
Bhutan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Burma	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
China	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyprus	X	X	X	X	X	X	76	23	0	X	X	X	X	X	X	31	55	14
India	87	13	0	89	11	0	X	X	X	47	51	3	47	50	4	X	X	X
Indonesia	98	3	0	98	2	0	X	X	X	67	21	12	69	18	14	X	X	X
Iran	53	46	1	X	X	X	X	X	X	17	69	14	X	X	X	X	X	X
Iraq	57	36	7	49	49	2	X	X	X	2	19	79	8	66	26	X	X	X
Israel	X	X	X	68	30	3	X	X	X	X	X	X	12	30	58	X	X	X
Japan	98	2	0	99	2	0	98	2	0	84	16	0	83	17	0	79	21	0
Jordan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Kampuchea, Dem	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Korea, Dem People's Rep	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Korea, Rep	100	0	0	100	0	0	X	X	X	100	0	0	100	0	0	X	X	X
Kuwait	X	X	X	74	23	3	X	X	X	X	X	X	13	47	37	X	X	X
Lao People's Dem Rep	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lebanon	80	20	1	82	17	1	X	X	X	39	45	17	22	43	35	X	X	X
Malaysia	89	10	1	X	X	X	X	X	X	30	14	56	X	X	X	X	X	X
Mongolia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nepal	X	X	X	97	3	0	X	X	X	X	X	X	72	27	1	X	X	X
Oman	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pakistan	80	20	0	68	31	1	73	26	0	32	68	0	30	58	11	34	57	9
Philippines	81	19	0	85	15	0	X	X	X	43	45	12	48	38	14	X	X	X
Qatar	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Saudi Arabia	X	X	X	77	20	2	X	X	X	X	X	X	15	39	46	X	X	X
Singapore	X	X	X	100	0	0	X	X	X	X	X	X	98	0	0	X	X	X
Sri Lanka	97	3	0	98	2	0	X	X	X	53	20	28	58	42	0	X	X	X
Syrian Arab Rep	X	X	X	62	36	3	X	X	X	X	X	X	11	57	32	X	X	X
Thailand	72	28	0	X	X	X	72	28	0	43	57	0	X	X	X	39	61	0
Turkey	58	41	1	X	X	X	62	37	1	22	65	13	X	X	X	21	71	8
United Arab Emirates	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Viet Nam	89	11	0	X	X	X	X	X	X	61	29	11	X	X	X	X	X	X
Yemen	X	X	X	X	X	X	89	11	0	X	X	X	X	X	X	44	52	5
Yemen, Dem	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EUROPE																		
Albania	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Austria	42	53	5	41	54	5	X	X	X	5	45	51	5	47	49	X	X	X
Belgium	62	37	1	53	46	1	44	53	3	16	73	11	10	77	13	6	74	20
Bulgaria	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Czechoslovakia	X	X	X	98	2	1	90	10	0	X	X	X	7	5	88	7	6	87
Denmark	19	78	3	10	84	7	14	77	9	4	78	18	1	73	26	2	63	35
Finland	53	47	0	36	63	1	X	X	X	28	68	4	53	46	1	X	X	X
France	29	65	6	31	61	8	28	60	12	5	67	29	5	62	34	4	54	42
German Dem Rep	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Germany, Fed Rep	55	44	1	39	59	2	X	X	X	17	71	12	9	77	14	X	X	X
Greece	X	X	X	80	21	0	X	X	X	X	X	X	45	53	3	X	X	X
Hungary	X	X	X	99	0	0	100	0	0	X	X	X	5	0	95	3	0	74
Ireland	17	76	7	20	73	7	X	X	X	3	65	32	3	65	32	X	X	X
Italy	76	23	1	76	23	1	X	X	X	20	43	36	18	40	42	X	X	X
Luxembourg	X	X	X	25	63	13	X	X	X	X	X	X	3	83	14	X	X	X
Malta	75	25	0	91	9	0	97	3	0	77	23	0	77	23	0	83	17	0
Netherlands	54	46	1	35	64	1	X	X	X	12	79	9	6	85	9	X	X	X
Norway	69	31	0	57	43	1	X	X	X	42	56	2	34	64	2	X	X	X
Poland	63	37	0	62	38	0	X	X	X	24	61	15	26	74	0	X	X	X
Portugal	X	X	X	82	17	1	X	X	X	X	X	X	18	31	51	X	X	X
Romania	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spain	50	45	5	X	X	X	X	X	X	6	29	65	X	X	X	X	X	X
Sweden	37	60	3	26	67	7	X	X	X	10	68	22	16	64	21	X	X	X
Switzerland	X	X	X	45	54	1	X	X	X	X	X	X	45	67	71	X	X	X
United Kingdom	32	49	19	22	52	26	X	X	X	2	24	74	1	20	79	X	X	X
Yugoslavia	71	29	0	74	26	0	X	X	X	33	57	11	33	48	19	X	X	X
USSR	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OCEANIA																		
Australia	7	25	69	8	24	69	X	X	X	0	0	100	0	0	100	X	X	X
Fiji	X	X	X	58	42	0	85	14	1	X	X	X	13	87	0	17	41	42
New Zealand	3	36	61	5	29	67	X	X	X	0	4	96	0	3	98	X	X	X
Papua New Guinea	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Solomon Islands	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ANTARCTICA																		

Source: U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = data not available.
For additional information, see Sources and Technical Notes.

Table 5.5 CROPLAND SOIL EROSION IN SELECTED COUNTRIES, 1970s AND 1980s

	Extent and Location	Affected Area as Percentage of Total Area	Amount of Erosion (metric tons per year)	Rate of Erosion (metric tons per hectare per year)	Year of Estimate
Ethiopia	Central Highland Plateau (47 million ha)	43	1.6 billion	34	1970s
Lesotho	Grazing and Arable Lands (2.7 million ha)	88	18.5 million	7	X
Niger	Small Watershed (11,700 ha)	0.01	468 thousand	40	X
Nigeria	State of Imo (900,000 ha)	1	13 million	14.4	1974
Madagascar	Mostly Cropland (45.9 million ha)	79	X	25–250	1970s
Zimbabwe	Area with Moderate to Severe Erosion (304,000 ha)	0.8	1[illegible] million	50	1979
Guatemala	Western Highlands	X	X	5–35	1979
Jamaica	Upper Yalluhs Valley	X	X	90	X
United States	Total Cropland (169 million ha)	19	1.66 billion	9.6	1982
Argentina, Paraguay, and Brazil	La Plata River Basin	X	95 million	18.8	X
Ecuador	High Sierra	X	X	210–564	X
Peru	Entire Country (128 million ha)	100	1.9 billion	15	X
China	Loess Plateau Region (60 million ha)	6.4	X	11–251	1980
India	Seriously Affected Cropland (80 million ha)	27	6 billion	75	1975
Nepal	Entire Country (13.7 million ha)	100	240 million	35–70	X
Belgium	Central Belgium	X	X	10–25	1970s

Source: World Resources Institute, International Institute for Environment and Development.
X = not available.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 5.1 Agricultural Production, 1964–84

Sources: Data for 1964–66: U.N. Food and Agriculture Organization (FAO), unpublished data, 1985. Total agricultural production for 1982–84 and yields for 1974–76 and 1982–84: FAO, *Production Yearbook 1984* (FAO, Rome, 1985). Agricultural production per agricultural worker, 1982–84: FAO, unpublished data, 1985.

Indexes of agricultural production represent the disposable output (after deduction for feed and seed) of a country's agriculture sector relative to the base period 1974–76. The index for a given year is calculated as follows: the disposable output of a commodity in weight or volume terms is multiplied by the 1974–76 unit value of the commodity. The product of this equation is the total value of the crop for that year in terms of 1974–76 prices. The values of all crop and livestock products are totaled to derive the value of all agricultural production in 1974–76 prices. The aggregate output for other years is then divided by the aggregate output for 1974–76 and multiplied by 100 to obtain the index number.

Indexes for continents and the world are computed by converting national production figures in local currencies to U.S. dollar equivalents using International Monetary Fund (IMF) exchange rates. The country outputs are totaled to derive the regional and global aggregates.

Index numbers of agricultural production include all crop and livestock products originating in each country for which information is available. Agricultural labor data are collected by the International Labor Organization (ILO). See Chapter 1, "Basic Economic Indicators," introduction, and Table 1.2, Sources and Technical Notes.

Yields are calculated from national production and area data. Production data include cereal used as feed and seed. Area data relate to the area harvested rather than the area sown. Cereals refer to all cereals (wheat, maize, rice, etc.) harvested for dry grain, exclusive of crops cut for hay or harvested green. Roots and tubers refer to all root crops grown principally for human consumption (potatoes, cassava, yams, taro, etc.); root crops grown principally for feed (turnips, swedes, mangels) are excluded.

Most of the data in Tables 5.1, 5.2, 5.3, 5.4, and 4.1 (see Chapter 4) are supplied by national agriculture ministries in response to annual FAO questionnaires, or are derived from agricultural censuses. FAO compiles data from more than 200 countries and many other sources, and enters them into a computerized database. The database facilitates the calculation of analytical indicators such as agricultural and food production indexes and ratios of calorie self-sufficiency. However, many gaps exist in the data, which FAO fills by preparing its own estimates. As more information becomes available, FAO corrects its estimates and recalculates the whole time series as necessary.

Countries collect many kinds of information through agricultural censuses: the size and age distribution of the agricultural labor force; the amount of land planted in various crops; the degree of farm mechanization; the use of fertilizers, pesticides and irrigation, etc. Most of the aggregate data are broken down by size-classes of holdings. For example, of the 2.5 million wheat holdings counted in Turkey's 1980 census of agriculture, 53,000 were smaller than 0.5 hectares, and 637,000 were between 5 and 10 hectares. Similar data are reported for holdings of 1–2 hectares, 2–3 hectares, 3–4 hectares, 4–5 hectares, 10–20 hectares, 20–50 hectares, and 50–100 hectares.

FAO has conducted world censuses of agriculture in 1950, 1960, 1970, and 1980. The 1980 census is still in progress. FAO's predecessor, the International Institute of Agriculture, also conducted a census in 1930. The table below summarizes the number of countries that have participated in the 1960, 1970, and 1980 censuses of agriculture. The table includes former colonies whose censuses were conducted by the colonial administration. The table excludes countries that are not independent.

	1960 Census	1970 Census	1980 Census[a] Plan to Participate	1980 Census[a] Undecided or No Reply
Europe	17	24	20	4
North America[b]	2	2	2	0
Latin America	19	24	19	10
Near East[c]	7	10	15	6
Far East	13	10	10	9
Africa[c]	26	22	29	12
Oceania	4	3	4	1
	88	95	99	42

Notes:
a. Information as of May 1981. FAO sent an exploratory questionnaire in 1977 to 147 member countries. A second questionnaire was sent to 152 countries in May 1980. Replies received by May 1981 are included in this table.
b. United States and Canada.
c. Libya, Egypt, Sudan, Djibouti, and Somalia are included in Near East and excluded from Africa.

Table 5.2 Agricultural Inputs, 1964–83

Sources: Data for 1964–66: U.N. Food and Agriculture Organization (FAO), unpublished data, 1985. Arable and permanent cropland, irrigated land, and tractors, 1974–76 and 1981–83: FAO, *Production Yearbook 1983 and 1984* (FAO, Rome, 1984 and 1985). Fertilizer Consumption 1974–76: FAO, *Fertilizer Yearbook 1983* (FAO, Rome, 1984). Fertilizer consumption 1981–83: FAO, "Monthly Bulletin of Statistics," April 1985.

Arable and permanent cropland is defined in the technical note in Chapter 4, "Land Use and Cover"; see the Technical Note for Table 4.1. Irrigated land refers to areas purposely provided with water, including land flooded by river water for crop production or pasture improvement, whether this area is irrigated several times or only once during the year.

Fertilizer use refers to application of nutrients in terms of nitrogen (N), phosphate (P_2O_5) and potash (K_2O). The fertilizer year is July 1–June 30; for 1964–66, fertilizer use refers to the split years ending in 1964, 1965, and 1966. Data for 1974–76 are the average of the 1974–75 and 1975–76 fertilizer years. Data for 1981–83 are the average of the 1981–82 and 1982–83 fertilizer years.

Tractors refer to total wheel and crawler tractors used in agriculture; garden tractors are excluded.

Refer to the Technical Note for Table 5.1 for detailed information on data collection and analysis.

Table 5.3 Food Production and Consumption, 1964–84

Sources: Data for 1964–66: U.N. Food and Agriculture Organization (FAO), unpublished data, 1985. Data for 1982–84: FAO, *Production Yearbook 1984* (FAO, Rome, 1985). Data for calories domestically produced as percentage of total supply: FAO, *Socio-economic Indicators Relating to the Agricultural Sector and Rural Development*, Economic and Social Development Paper 40 (FAO, Rome, 1984).

Indexes of food production are computed in the same manner as indexes of agricultural production. Refer to the Technical Note for Table 5.1 for details. The food production index covers the subset of agricultural crops that are edible and contain nutrients. Coffee and tea, although edible, are excluded from the food production index because they have virtually no nutritive value.

The proportion of the total calorie supply produced domestically is calculated from the Supply Utilization Accounts developed by FAO. The numerator of the fraction, calories domestically produced, is computed on a commodity-by-commodity basis from production data. The denominator is the sum of the domestic calorie production (the numerator); net imports of calories in foodstuffs, and the calories supplied by the net drawdown of food stocks.

Refer to the Technical Note for Table 5.1 for detailed information on data collection and analysis.

Table 5.4 Land Distribution, 1960–80

Sources: Data for 1960: U.N. Food and Agriculture Organization (FAO), *Report on the 1960 World Census of Agriculture: Analysis and International Comparison of Results* (FAO, Rome, 1971). Data for 1970: FAO, *1970 World Census of Agriculture: Analysis and International Comparison of Results* (FAO, Rome, 1981). Data for 1980: FAO, *Report on the 1980 World Census of Agriculture*, Census Bulletins 2–13, October 1983–May 1985.

The years 1960, 1970, and 1980 refer to the World Censuses of Agriculture organized by FAO. Data for 1960 were compiled from national censuses conducted between 1958 and 1964. The 1970 round of censuses covered the period 1966 to 1974. The 1980 census round will include national censuses conducted between 1977 and 1985, with the majority falling between 1979 and 1981. The specific dates of country censuses are reported in the sources. Refer to the Technical Note for Table 5.1 for details of participation in the three most recent censuses.

An agricultural holding, as defined in the *World Census of Agriculture*, is a unit of agricultural production comprising all livestock kept and all land used wholly or partly for agricultural purposes. It may be operated by one person or more, regardless of title, legal form, size, or location. A holding may consist of one or more parcels of land, and may consist of livestock without agricultural land. Common grazing land is not considered a holding. Establishments producing only forest products, race horses, fish, frogs, dogs, or wild game are not considered holdings. Land rented from an owner is considered within the holding of the operator and outside the holding of the owner.

Agricultural area refers to all land under temporary or permanent crops and land used as permanent pasture. For detailed definitions, refer to Chapter 4, "Land Use and Cover"; see the Technical Note for Table 4.1.

FAO strives to achieve comparability of data across countries by circulating standard questionnaires; preparing detailed program documents; conducting regional training seminars, etc. However, to accommodate local circumstances, countries often deviate from the standard definitions and survey techniques, making comparisons across countries (or across years for the same country) difficult. For example, the censuses of many countries exclude holdings that are below some minimum size or economic importance. In 1960, France counted all holdings larger than 1 hectare or larger than 0.2 hectares if engaged in specialized agriculture. Zambia's census covered only European holdings larger than 10.11 hectares. Panama counted holdings larger than 0.5 hectares, but excluded approximately 8,300 holdings operated by indigenous populations.

In 1970 and 1980, France retained the same minimum size criteria. In 1970, Zambia's census covered the land under crops for the traditional sector and the total area of holdings for the modern sector. Panama's censuses for 1970 and 1980 counted holdings of any size, but did not include holdings in the indigenous zones. Refer to FAO's census publications for details concerning the coverage of censuses and the definitions and classifications used.

Table 5.5 Cropland Soil Erosion in Selected Countries, 1970s and 1980s

Sources: Compiled by World Resources Institute and International Institute for Environment and Development from sources listed below.

- *Ethiopia:* U.N. Food and Agriculture Organization, *Protect and Produce: Soil Conservation for Development* (FAO, Rome, 1984), p. 17.
- *Lesotho:* Arid Lands Information Center, University of Arizona, *Draft Environmental Profile of the Kingdom of Lesotho* (University of Arizona, Tucson, Arizona, 1982), p. 77.
- *Niger:* S.A. El-Swaify, *et al.* "Soil Immersion by Water" in *Natural Systems for Development: What Planners Need to Know* (MacMillan Publishing Company, New York, 1983).
- *Nigeria:* G.E. Osuji, "The Gullies of Imo," *Journal of Soil and Water Conservation*, July-August 1984, Vol. 39, No. 4, pp. 246–247.
- *Madagascar:* P. Randrianarijaona, "The Erosion of Madagascar," *AMBIO*, Vol. 12, No. 6, pp. 308–311 (1983).
- *Zimbabwe:* Arid Lands Information Center, University of Arizona, *Draft Environmental Profile of Zimbabwe* (University of Arizona, Tucson, Arizona, 1982), p. 89.
- *Guatemala:* Institute of Ecology, University of Georgia, *An Environmental Profile of Guatemala* (University of Georgia, Athens, Georgia, 1981), p. 18.
- *Jamaica:* U.N. Food and Agriculture Organization (FAO), *Strengthening the National Soil Conservation Programme for Integrated Watershed Development, Jamaica,*

Terminal Report (FAO, Rome, 1982).

- *United States:* Rosenberry and English in "Erosion Control Practices: Impact of Actual Versus Most Effective Use," in *Conservation Needs and Opportunities* (Board of Agriculture, National Research Council). Data were taken from the 1982 Natural Resources Inventory, U.S. Department of Agriculture, Soil Conservation Service.
- *Argentina:* Organization of American States (OAS), *Cuenca del Rio de la Plata: Estudio para su Platificación y Desarollo* (OAS, Washington, D.C., 1974).
- *Ecuador:* S.A. El-Swaify, *et al.* "Soil Immersion by Water," in *Natural Systems for Development: What Planners Need to Know* (MacMillian Publishing Company, New York, 1983).
- *Peru:* Interview with Lorenzo Chang Novarro (Director of Peru's Department of Watershed, Soil, and Water Conservation) in Abraham Lama, "Peru: Rapid Soil Erosion Threatens Peruvian Agriculture," *Latin America Links*, 1984.
- *China:* Lee Hsiao-tseng, "Soil Conservation in China's Loess Plateau," *Journal of Soil and Water Conservation*, Vol. 39 No. 4 (1984), pp. 306–307. Zhu Ling "Study Aims to Lift Flood Threat of Yellow River," *China Daily*, Vol. 4, No. 1069 (1984).
- *India:* Das, "Soil Conservation Practices and Erosion Control in India—A Case Study," *Soils Bulletin*, No. 33 (FAO, Rome, 1977).
- *Nepal:* Science and Technology Division, Library of Congress, *Draft Environmental Report on Nepal* (Library of Congress, Washington, D.C., 1979), p. 43.
- *Belgium:* G. Richter, "Aspects and Problems of Erosion Hazard in the EEC Countries," in *Soil Erosion* (Commission of the European Communities, Luxembourg, 1982), p. 11.

Soil erosion is the removal of soil from the land by the erosive processes of moving water and wind. There are two main types of water erosion: "sheet erosion," which occurs when beating rain and flowing water remove thin layers of soil from a field, and "rill erosion," which occurs as flowing water carves out channels in the soil.

The natural rate of erosion is determined by climate, topography, soil type, and vegetative cover. It can be exacerbated by poor agricultural practices, overgrazing of livestock, and deforestation. On large areas of cropland the loss of top soil is greater than the amount added naturally, and as a result the land becomes less fertile and less productive.

There are three locations within a watershed at which soil erosion rates can be estimated. The "upstream methods" estimate the amount of erosion based on field observations. The "midstream methods" estimate the volume of soil erosion based on the sediment loads carried by rivers and other watercourses. The "downstream methods" estimate the severity of soil erosion based on the volume of sediment deposited in lakes, reservoirs, or at the drainage point of a water basin.

Erosion rates are not strictly comparable across countries because different methods of estimation have been used and most of the sources did not identify which type of estimation method was used. Countries measure erosion differently depending on the causes of the problem and on the techniques and methods employed. In the United States, erosion from wind and/or rain was estimated depending on the location sampled. In Madagascar, where the problems of erosion are caused by heavy rainfall, only water erosion was estimated.

There are other important caveats concerning the data:

1. Most of the field measurements of erosion rates have been carried out in areas where sheet and rill erosion is most serious: parts of North and South America, India, and China. Much less has been done to measure wind erosion in the arid and semi-arid lands of sub-Saharan Africa and Southern Africa.
2. Some of the data in the table are point estimates, based on a few measurements made at one point in time and extrapolated to reflect an annual average.
3. An attempt has been made to choose countries and sites where soil erosion can be associated with agricultural practices. However, no attempt has been made to correct soil erosion estimates for the amounts of soil eroded by factors unrelated to cultivation of cropland.

For a recent and detailed review of soil erosion in developing countries, see Alfredo Sfeir-Younis, *Soil Conservation in Developing Countries*, (The World Bank, unpublished manuscript, Washington, D.C., 1985).

6. Forests and Rangelands

Forests and rangelands together occupy roughly three-quarters of the world's land surface. However, the statistics available with which to evaluate changes in these lands are weak, particularly when compared to information on cultivated lands.

Some of the best data on forests are for areas that are extensive and remote, such as the vast forested areas of Canada, the Soviet Union, Zaire, and Brazil, which can be monitored from satellites, or for actively managed areas such as plantations. Statistics are least available where they are most needed: in developing countries without the resources to monitor and manage forests and where competing demands for cropland, fuelwood, and industrial timber are rapidly changing the forests.

Table 6.1 provides information on the extent, change, and management of forests. The definitions and techniques used to measure forests greatly influence the numbers shown. For example, the trees of a closed forest fully shade the ground, preventing the growth of grasses. In an open forest, trees cover at least 10 percent of the ground, permitting a nearly continuous grass layer on the forest floor. (Areas meeting this description are classified as rangeland in some countries.)

Omitted from the table are forest fallow, about 400 million hectares of land that is cut, burned, and cultivated for a year or two and then allowed to return to trees until the next slash and burn cycle. Also omitted are 600 million hectares of shrubland. In densely settled rural areas, closed forests may have been largely degraded or even eliminated and replaced by shrubs that are important sources of fuelwood, forage, and other products.

Deforestation is often defined imprecisely. In Table 6.1 it refers to the clearing of closed forested land and its subsequent use for agriculture or settlement. Other alterations, such as logging of closed forests, or active management of productive stands, are not considered deforestation.

Forest management is the active management of forest growth or regeneration in accordance with a plan. Such plans include logging controls, fire and disease prevention and treatment, and sylvicultural research. Protected areas are legally defined forests in national or scientific parks where timber exploitation is forbidden.

Countries with the largest areas of forest are the Soviet Union, Brazil, Canada, the United States, China, and Indonesia. Those with the highest estimated rates of deforestation are Ivory Coast, Paraguay, Nigeria, Costa Rica, and Nepal. Although a deforestation rate of less than 1 percent per year is small in relative terms, in countries such as Brazil, India, and Indonesia, even that rate can mean extensive loss of forest land.

There has been considerable controversy over the estimates of tropical deforestation. Global reviews conducted in the early 1970s, for example, found less tropical forest and higher rates of deforestation than those shown here. The different estimates can be attributed largely to different definitions and measurement techniques. The figures in Table 6.1, collected in the late 1970s and first published in 1981, may not reflect current conditions.

Table 6.2 provides measures of wood harvests, as well as estimates of the economic value of forest products that enter into international trade. The figures reveal important shifts: Brazil and Malaysia have dramatically increased exports; Egypt has dramatically increased imports; and Nigeria has shifted from a net exporter to a net importer.

Missing from these tables are a number of data series that would be useful to policymakers, foresters, and landowners who need to plan the future use of forest land. Among these are the volume of economically valuable trees for timber production, changes in forest conditions and composition of flora and fauna, and better information on forest management.

Table 6.3 presents statistics on desertification, based on a global review carried out for the United Nations Environment Program (UNEP). The percentage figures (which should be regarded as informed estimates) indicate the amount of land that is believed to be reduced in productivity by 25 percent or more from its original condition. The Sudano-Sahelian region, which has experienced a decline in precipitation and an increase in livestock grazing over the past 30 years, reports increasing desertification. More importantly, 14 of the 19 countries surveyed reported increases in rates of desertification; 5 of the 14 reported significant increases. Desertification pressures are greatest on rangelands and recently deforested lands.

Table 6.1 FOREST RESOURCES, 1980s

	Extent of Forest and Woodland, 1980 (thousand hectares)		Deforestation of Closed Forests, 1981–85		Reforestation 1980s (thousand hectares per year)	Managed Closed Forests 1980 (thousand hectares)	Protected Forest Areas 1980 (thousand hectares)
	Open	Closed	Average Annual Extent (thousand hectares per year)	Percent per Year			
WORLD	**1352460**	**2936693**					
AFRICA	**489374**	**235805**					
Algeria	2500	490	X	X	X	X	X
Angola	50700	4471	44	1.0	0	X	X
Benin	3820	47	1	2.6	0	X	X
Botswana	32560	0	X	X	X	X	X
Burkina Faso	7200	120	X	X	2	X	X
Burundi	14	222	1	0.3	1	X	16
Cameroon	7700	18105	80	0.4	1	X	X
Cape Verde	0	1	X	X	X	X	X
Central African Rep	32300	3595	5	0.1	0	X	X
Chad	13000	532	X	X	1	X	X
Comoros	X	X	X	X	X	X	X
Congo	0	21508	22	0.1	2	X	130
Djibouti	100	6	X	X	X	X	X
Egypt	30	1	X	X	X	X	X
Equatorial Guinea	0	1295	3	0.2	0	X	X
Ethiopia	22800	5332	8	0.2	6	X	X
Gabon	75	20690	15	0.1	0	X	X
Gambia	150	78	2	2.8	X	X	X
Ghana	6975	2471	22	0.9	3	1167	397
Guinea	8600	2072	36	1.7	X	X	X
Guinea-Bissau	1445	664	17	2.6	X	X	X
Ivory Coast	5376	4907	290	5.9	3	1	648
Kenya	1255	2605	19	0.7	7	70	570
Lesotho	0	0	X	X	X	X	X
Liberia	40	2063	46	2.2	1	X	X
Libya	390	70	X	X	X	X	X
Madagascar	2900	12960	150	1.2	12	X	930
Malawi	4085	989	X	X	6	X	146
Mali	8800	19	X	X	0	X	X
Mauritania	15000	0	X	X	X	X	X
Mauritius	29	2	X	X	X	X	X
Morocco	4800	400	X	X	20	X	X
Mozambique	14500	1189	10	0.8	1	X	25
Niger	2900	60	X	X	1	X	X
Nigeria	8800	7583	300	4.0	14	X	X
Rwanda	110	412	3	0.8	2	X	16
Senegal	10825	345	X	X	2	X	63
Sierra Leone	1315	798	6	0.8	0	X	X
Somalia	7510	650	4	0.2	2	X	X
South Africa	2800	1350	X	X	X	X	X
Sudan	47000	2532	4	0.2	11	50	X
Swaziland	50	100	X	X	X	X	X
Tanzania, United Rep	40600	2658	10	0.4	7	X	410
Togo	1380	304	2	0.7	0	X	X
Tunisia	350	400	X	X	X	X	X
Uganda	5250	879	10	1.1	1	442	58
Zaire	71840	105975	182	0.2	X	X	5700
Zambia	26500	3390	40	1.2	3	5	220
Zimbabwe	15000	465	X	X	X	X	X
NORTH AMERICA	**275320**	**530451**					
Barbados	X	X	X	X	X	X	X
Canada	172300	264100	X	X	720	X	4870
Costa Rica	X	1664	65	3.9	0	X	320
Cuba	0	3025	2	0.1	11	200	X
Dominican Rep	0	685	4	0.6	0	X	X
El Salvador	0	155	5	2.9	0	X	X
Guatemala	X	4596	90	2.0	3	X	62
Haiti	0	58	2	3.1	0	X	X
Honduras	200	3797	90	2.4	0	58	X
Jamaica	0	195	2	1.0	1	X	2
Mexico	X	47840	595	1.2	17	X	360
Nicaragua	0	4508	121	2.7	0	250	X
Panama	0	4204	36	0.9	1	X	X
Trinidad and Tobago	0	368	1	0.2	1	14	X
United States	102820	195256	X	X	1775	102362	31198
SOUTH AMERICA	**247875**	**657670**					
Argentina	32300	7670	X	X	38	X	X
Bolivia	22750	44013	87	0.2	0	X	X
Brazil	157000	396030	1480	0.4	346	X	4660
Chile	2430	6250	X	X	50	X	X
Colombia	5300	47351	820	1.7	8	[illegible]	2280
Ecuador	X	14679	340	2.3	4	X	350
Guyana	25	18487	3	0.0	0	X	12
Paraguay	26260	4100	190	4.6	0	X	90
Peru	1120	70520	270	0.4	4	X	850
Suriname	690	14915	3	0.0	0	X	580
Uruguay	0	580	X	X	5	X	X
Venezuela	X	33075	125	0.4	14	X	4500

Table 6.1

	Extent of Forest and Woodland, 1980 (thousand hectares)		Deforestation of Closed Forests, 1981–85		Reforestation 1980s (thousand hectares per year)	Managed Closed Forests 1980 (thousand hectares)	Protected Forest Areas 1980 (thousand hectares)
	Open	Closed	Average Annual Extent (thousand hectares per year)	Percent per Year			
ASIA	**109408**	**497567**					
Afghanistan	1300	200	X	X	X	X	X
Bahrain	0	0	X	X	X	X	X
Bangladesh	0	2207	8	0.4	9	795	52
Bhutan	40	2170	2	0.1	1	X	X
Burma	0	32101	105	0.3	2	3419	299
China	45000	125000	X	X	4552	X	X
Cyprus	24	153	X	X	X	153	25
India	5393	72521	147	0.2	120	32557	6779
Indonesia	3000	123235	600	0.5	187	40	5430
Iran	10500	1900	X	X	X	X	X
Iraq	1880	30	X	X	X	X	X
Israel	20	80	X	X	2	56	7
Japan	1390	23890	X	X	240	X	X
Jordan	28	54	X	X	X	X	X
Kampuchea, Dem	5100	7616	25	0.3	0	X	X
Korea, Dem Peoples Rep	X	8970	X	X	200	X	X
Korea, Rep	240	6275	X	X	152	X	X
Kuwait	0	15	X	X	X	X	X
Lao People's Dem Rep	5215	8520	100	1.2	1	X	X
Lebanon	50	35	X	X	X	X	X
Malaysia	0	21256	255	1.2	4	2499	959
Mongolia	5000	10000	X	X	X	X	X
Nepal	180	2128	84	3.9	2	X	330
Oman	0	0	X	X	X	X	X
Pakistan	295	3785	7	0.2	7	410	15
Philippines	0	12510	91	0.7	42	X	690
Qatar	0	0	X	X	X	X	X
Saudi Arabia	1200	0	X	X	X	X	X
Singapore	X	X	X	X	X	X	X
Sri Lanka	X	2782	58	2.1	10	X	193
Syrian Arab Rep	330	90	X	X	10	X	X
Thailand	6440	10375	252	2.4	13	X	2220
Turkey	11343	8856	X	X	82	8856	139
United Arab Emirates	0	3	X	X	X	X	X
Viet Nam	1340	10810	65	0.6	20	70	560
Yemen	2500	0	X	X	X	X	X
Yemen, Dem	1600	0	X	X	X	X	X
EUROPE	**21787**	**137005**					
Albania	0	1280	X	X	X	X	X
Austria	0	3754	X	X	21	1489	0
Belgium	80	682	X	X	19	272	0
Bulgaria	400	3328	X	X	50	3600	100
Czechoslovakia	145	4435	X	X	37	4435	X
Denmark	18	466	X	X	X	330	56
Finland	3340	19885	X	X	158	10578	294
France	1200	13875	X	X	51	2957	92
German Dem Rep	285	2700	X	X	X	2697	85
Germany, Fed Rep	218	6989	X	X	62	3886	X
Greece	3242	2512	X	X	X	1603	55
Hungary	25	1612	X	X	19	1612	41
Ireland	33	347	X	X	9	298	0
Italy	1700	6363	X	X	15	699	162
Luxembourg	X	X	X	X	X	38	0
Malta	X	X	X	X	X	X	X
Netherlands	61	294	X	X	2	225	0
Norway	1066	7635	X	X	79	1130	60
Poland	138	8588	X	X	106	8099	103
Portugal	349	2627	X	X	4	X	7
Romania	410	6255	X	X	X	5940	X
Spain	3905	6906	X	X	92	2007	40
Sweden	3442	24400	X	X	207	14301	230
Switzerland	189	935	X	X	7	627	7
United Kingdom	151	2027	X	X	40	1505	0
Yugoslavia	1390	9100	X	X	X	6300	400
USSR	**137000**	**791600**	**X**	**X**	**4540**	**791600**	**20000**
OCEANIA	**71696**	**86595**					
Australia	65085	41658	X	0.0	62	X	X
Fiji	350	850	X	0.0	4	X	X
New Zealand	2300	7200	X	0.0	43	X	X
Papua New Guinea	3945	34447	22	0.1	2	0	55
Solomon Islands	16	2440	X	0.0	2	X	X
ANTARCTICA							

Sources: U.N. Food and Agriculture Organization; U.N. Economic Commission for Europe; U.N. Environment Program.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 6.2 FOREST PRODUCTS, 1972–83

	Average Annual Removals (thousand cubic meters)						Average Annual Trade in Forest Products (thousand US dollars)			
	Total Roundwood		Fuelwood and Charcoal		Industrial Wood		Imports		Exports	
	1981–83	Percent Change Over 1972–74	1981–83	Percent Change Over 1972–74	1981–83	Percent Change Over 1972–74	1972–74	1981–83	1972–74	1981–83
WORLD	**2990590**	**15**	**1604110**	**25**	**1386480**	**5**	**25020252**	**54271302**	**12546694**	**48376687**
AFRICA	**456909**	**29**	**403950**	**29**	**52952**	**24**	**734271**	**2033054**	**432445**	**1104140**
Algeria	1678	24	1461	24	217	27	101364	345655	1337	0
Angola	8986	19	7663	22	1323	9	4712	504	9239	98
Benin	4080	31	3868	30	212	32	143	5643	X	X
Botswana	785	10	729	10	56	22	820	1640	X	X
Burkina Faso	7087	22	6770	26	324	-28	826	4458	X	X
Burundi	3434	22	3395	22	39	26	79	177	X	X
Cameroon	10157	24	7994	18	2163	55	4672	11478	26586	108227
Cape Verde	X	X	X	X	X	X	499	902	X	X
Central African Rep	3061	8	2544	23	517	-31	164	1790	7673	26555
Chad	7946	20	7479	20	468	21	1381	1438	X	X
Comoros	X	X	X	X	X	X	X	X	X	X
Congo	2205	12	1470	26	735	-8	661	1989	20433	50470
Djibouti	X	X	X	X	X	X	225	38	X	X
Egypt	1883	25	1801	25	88	22	93113	541929	X	X
Equatorial Guinea	465	10	415	12	50	0	X	X	269	3477
Ethiopia	28989	21	27630	22	1692	34	2216	8296	4	X
Gabon	2525	-25	1222	8	1303	-42	292	3969	56821	145804
Gambia	789	8	773	7	17	67	100	172	X	X
Ghana	9803	26	7284	28	2519	20	13512	2937	86385	14487
Guinea	3634	21	3085	22	549	16	X	X	3646	X
Guinea Bissau	527	11	422	11	105	9	131	98	130	130
Ivory Coast	11587	15	6963	39	4624	-9	10875	18171	233936	333703
Kenya	28178	44	26763	42	1415	81	32920	23228	2403	7983
Lesotho	293	18	293	18	X	X	X	X	X	X
Liberia	4491	25	3957	30	534	-2	1086	5553	15296	45686
Libya	630	24	536	19	94	69	72765	127948	X	X
Madagascar	6262	22	5455	19	807	43	2770	7989	704	166
Malawi	6256	33	5886	33	371	31	4104	16454	220	615
Mali	4457	28	4175	28	282	24	617	1174	X	X
Mauritania	53	22	7	33	46	21	X	X	X	X
Mauritius	33	-10	23	9	10	-36	3850	8709	X	X
Morocco	1606	49	1105	80	501	8	51449	154205	12826	21554
Mozambique	14199	47	13350	51	849	-2	6004	12830	10560	4641
Niger	3621	30	3397	30	224	30	406	285	X	X
Nigeria	83210	38	75850	33	7360	125	55798	223494	19149	748
Rwanda	5036	7	4802	3	293	389	232	2416	X	X
Senegal	3784	21	3277	21	507	28	7126	24458	X	X
Sierra Leone	7931	27	7784	27	147	13	1529	1130	X	X
Somalia	4885	66	4815	67	70	31	5237	5505	X	X
South Africa	19003	14	7000	1	12003	23	163526	260345	82544	242807
Sudan	37067	28	35417	28	1650	24	13408	14502	X	X
Swaziland	2223	21	560	26	1663	19	452	1539	26033	70220
Tanzania, United Rep	38571	31	37474	32	1097	7	8965	16850	1445	1338
Togo	724	28	568	28	156	28	356	483	10	X
Tunisia	2620	24	2513	24	107	27	31351	92035	3754	X
Uganda	25415	31	23933	31	1515	23	3735	3501	468	38
Zaire	30400	26	27990	28	2410	9	11552	5177	8621	17810
Zambia	9296	31	8808	30	488	46	12222	21877	140	X
Zimbabwe	6900	59	5546	45	1354	158	X	28201	X	7649
NORTH AMERICA	**612117**	**19**	**149627**	**180**	**462490**	**0**	**4634682**	**10359820**	**7163423**	**16079211**
Barbados	X	X	X	X	X	X	6505	24318	X	X
Canada	141061	4	5488	59	135573	3	386253	776067	4426255	10023162
Costa Rica	2624	0	1479	-3	1145	6	34441	73573	2897	19739
Cuba	3188	27	2803	32	385	0	61917	172618	X	X
Dominican Rep	566	20	557	26	9	-71	23119	63071	26	17
El Salvador	4446	34	4334	34	112	42	12950	33751	407	2838
Guatemala	6644	23	6459	31	185	-63	15177	61934	9137	17625
Haiti	5491	23	5252	24	239	0	2007	4987	114	X
Honduras	5106	23	4109	37	997	-14	19932	31228	36888	33663
Jamaica	48	-22	13	86	35	-36	28697	95535	54	2744
Mexico	19372	25	12965	31	6407	14	109815	547233	4970	10445
Nicaragua	3291	29	2411	34	880	17	8297	13654	6964	4270
Panama	2047	36	1708	24	339	181	19517	32506	884	950
Trinidad and Tobago	83	-19	22	12	61	-27	20056	122331	191	573
United States	417891	24	101922	483	315969	-1	3866178	8263347	2669032	5961685
SOUTH AMERICA	**284316**	**38**	**205156**	**25**	**79161**	**90**	**570651**	**1146548**	**334762**	**1365238**
Argentina	9962	2	6088	-2	3874	10	186427	255532	16102	11547
Bolivia	1348	20	1116	33	233	-18	3475	12468	6121	10324
Brazil	216571	43	159058	25	57513	138	179569	196610	202240	820264
Chile	13150	30	5798	16	7352	42	8604	43300	67068	333868
Colombia	16394	12	13627	21	2767	-18	40445	147481	8362	51869
Ecuador	7745	40	5592	49	2153	21	32452	82177	6295	33986
Guyana	201	-21	12	20	189	-23	3422	6329	2067	6260
Paraguay	6786	59	4374	30	2412	167	2771	9486	14906	69102
Peru	7792	22	6456	27	1337	2	30838	63795	4057	7119
Suriname	278	48	22	400	256	40	4175	12483	6133	10723
Uruguay	2556	70	2305	78	251	22	12074	22514	765	6296
Venezuela	1278	16	642	37	636	0	65754	293706	X	X

Table 6.2

	Average Annual Removals (thousand cubic meters)						Average Annual Trade in Forest Products (thousand US dollars)			
	Total Roundwood		Fuelwood and Charcoal		Industrial Wood		Imports		Exports	
	1981-83	Percent Change Over 1972-74	1981-83	Percent Change Over 1972-74	1981-83	Percent Change Over 1972-74	1972-74	1981-83	1972-74	1981-83
ASIA	**909430**	**16**	**700308**	**16**	**209123**	**18**	**5397608**	**12721855**	**2709911**	**5728626**
Afghanistan	6539	21	4991	26	1549	10	19238	28530	X	X
Bahrain	X	X	X	X	X	X	4610	27376	17	X
Bangladesh	31209	27	30269	28	940	5	8106	2132	3452	5078
Bhutan	3224	19	2946	19	278	17	X	143	X	501
Burma	18836	26	15817	27	3019	21	6081	11207	40795	120548
China	227847	25	154635	15	73212	56	272698	1419525	266715	524060
Cyprus	77	-12	20	-26	57	-6	18656	50189	122	165
India	228407	21	208538	20	19869	33	61820	212042	23737	26558
Indonesia	125476	5	112351	18	13126	-46	45217	196112	512776	917156
Iran	6707	7	2331	45	4376	-6	73094	245828	237	38
Iraq	129	27	79	29	50	25	55114	142321	X	X
Israel	118	53	11	-15	107	66	103070	225992	9165	13672
Japan	32536	-24	594	-61	31942	-22	3673023	6336158	410144	802193
Jordan	10	-3	6	42	4	-33	8114	65965	550	8855
Kampuchea, Dem	5118	1	4551	-1	567	14	1885	1885	173	173
Korea, Dem People's Rep	6110	19	5510	22	600	0	1879	1879	X	X
Korea, Rep	10160	28	6913	17	3247	59	336442	867897	262246	346154
Kuwait	X	X	X	X	X	X	28835	157524	2121	28058
Lao People's Dem Rep	3832	22	3605	23	227	3	886	816	1826	8706
Lebanon	221	-40	195	-44	25	27	34540	61873	3777	3239
Malaysia	40418	185	7193	26	33224	293	73866	215239	615444	1975786
Mongolia	2390	0	1350	0	1040	0	X	5913	4210	9300
Nepal	14370	23	13810	24	560	0	X	X	5166	11667
Oman	X	X	X	X	X	X	X	60267	X	X
Pakistan	18574	29	17980	29	594	25	35010	82740	145	X
Philippines	35223	6	27768	27	7454	-35	38902	77664	321309	385706
Qatar	X	X	X	X	X	X	2246	2505	X	X
Saudi Arabia	X	X	X	X	X	X	47360	676191	X	X
Singapore	X	X	X	X	X	X	166289	514131	162183	435254
Sri Lanka	8166	19	7489	17	676	37	9314	33182	18	4269
Syrian Arab Rep	38	-12	11	43	27	-24	36254	123491	512	1137
Thailand	39659	17	35475	24	4184	-22	47201	253005	32513	28976
Turkey	20130	-45	15000	-50	5130	-21	21144	70719	13323	29522
United Arab Emirates	X	X	X	X	X	X	X	X	X	X
Viet Nam	23181	23	20353	22	2828	31	5749	8669	X	X
Yemen	X	X	X	X	X	X	X	X	X	X
Yemen, Dem	264	26	264	26	X	X	2303	11498	32	29
EUROPE	**336348**	**2**	**54569**	**-2**	**281779**	**3**	**13027476**	**26151543**	**9690330**	**20831412**
Albania	2330	0	1608	0	722	0	2106	3833	773	730
Austria	13767	14	1413	39	12354	12	228254	572389	637614	1379109
Belgium	2901	-5	471	35	2430	-10	664606	1513544	365993	877881
Bulgaria	4862	1	1729	66	3134	-17	82988	147508	11727	18147
Czechoslovakia	19061	23	1723	-12	17339	28	80360	102285	139068	400092
Denmark	2950	52	367	242	2583	41	463313	763125	75666	230411
Finland	40225	-4	3534	-48	36691	5	109473	281332	1891022	4488921
France	38363	-3	10412	-3	27951	-3	1500857	2738679	628779	1253246
German Dem Rep	10459	28	734	47	9725	27	259150	458315	59233	93367
Germany, Fed Rep	30610	-1	4133	32	26476	-5	2219806	4997563	849341	2217544
Greece	2771	8	1991	1	780	32	139253	285423	11310	41870
Hungary	6444	18	2830	10	3614	25	239842	295205	52758	85844
Ireland	825	125	44	264	791	120	145854	318896	22698	37422
Italy	8836	5	4216	36	4620	-13	1334516	2945910	282792	565045
Luxembourg	X	X	X	X	X	X	X	X	X	X
Malta	X	X	X	X	X	X	8116	30850	X	X
Netherlands	906	-22	100	224	806	-28	943310	2067993	289502	672805
Norway	9803	12	788	33	9015	10	217663	426958	493236	781237
Poland	22499	11	2845	44	19654	7	143789	210109	92917	155806
Portugal	7799	9	500	-9	7299	10	61879	153869	143704	380649
Romania	22124	1	4349	-25	17775	10	41751	102132	218658	431685
Spain	13987	9	1379	-68	12609	49	431478	650252	80140	389557
Sweden	51373	-12	4425	69	46949	-16	180964	540233	2759613	4831007
Switzerland	4375	6	955	25	3420	2	308948	705867	94969	333162
United Kingdom	4151	17	151	-57	4000	25	3016297	5400479	260590	654405
Yugoslavia	14917	9	3874	2	11043	11	183096	395994	228224	510968
USSR	**356667**	**-8**	**82500**	**-2**	**274167**	**-9**	**283073**	**971475**	**1417413**	**2554726**
OCEANIA	**34803**	**23**	**8000**	**25**	**26802**	**23**	**372491**	**887007**	**229665**	**713333**
Australia	16882	33	2099	68	14782	29	326243	763200	91001	236792
Fiji	224	51	14	45	210	52	4719	11179	618	4300
New Zealand	10119	8	50	-85	10069	11	31640	87308	113462	373830
Papua New Guinea	6884	27	5533	22	1351	54	1270	X	18898	75336
Solomon Islands	512	21	210	18	302	23	190	592	4647	21367
ANTARCTICA										

Source: U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 6.3 DESERTIFICATION, EARLY 1980s

	Total Productive Drylands		Productive Dryland Types					
			Rangelands		Rainfed Croplands		Irrigated Lands	
	Area (million hectares)	Percent Desertified	Area (million hectares)	Percent Desertified	Area (million hectares)	Percent Desertified	Area (million hectares)	Percent Desertified
Total	**3257**	**61**	**2556**	**62**	**570**	**60**	**131**	**30**
Sudano-Sahelian Africa	473	88	380	90	90	80	3	30
Southern Africa	304	80	250	80	52	80	2	30
Mediterranean Africa	101	83	80	85	20	75	1	40
Western Asia	142	82	116	85	18	85	8	40
Southern Asia	359	70	150	85	150	70	59	35
USSR in Asia	298	55	250	60	40	30	8	25
China and Mongolia	315	69	300	70	5	60	10	30
Australia	491	23	450	22	39	30	2	19
Mediterranean Europe	76	39	30	30	40	32	6	25
South America and Mexico	293	71	250	72	31	77	12	33
North America	405	40	300	42	85	39	20	20

Source: U.N. Environment Program.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 6.1 Forest Resources, 1980s

Sources: Forest extent and reforestation: U.N. Food and Agriculture Organization (FAO), *Forest Resources 1980* (FAO, Rome, 1985). Forest loss, protection, and management: FAO and United Nations Environment Program (UNEP), *Tropical Forest Resources Assessment Project* (FAO, Rome, 1981). FAO and United Nations Economic Commission for Europe (ECE), *The Forest Resources of the ECE Region* (ECE, Geneva, 1985). Reforestation data for China: State Statistical Bureau, *China: A Statistics Survey in 1985*, (New World Press, Beijing, 1985), p. 30.

The U.N. Food and Agriculture Organization (FAO)/United Nations Environment Program (UNEP) study covers only the tropical moist forests in 76 tropical countries and thus should not (but occasionally does) count tropical dry forests or subtropical forests in these countries. The FAO/United Nations Economic Commission for Europe (ECE) report covers all types of forests in the 32 member countries of the ECE.

The forests and open woodland referred to in Table 6.1 are natural stands of woody vegetation in which trees are predominant. For the purpose of this definition, "natural" means all stands except plantations and includes stands that have been degraded to some degree by fire, logging, or agriculture. "Trees" are distinguished from shrubs on the basis of height: a mature tree has a single, well-defined stem and exceeds seven meters in height while a mature shrub is usually less than seven meters high.

Reforestation refers to the establishment of plantations for industrial and non-industrial uses. Plantations are formed in two ways: a. *by afforestation*, forest stands established artificially on land that previously did not carry forest, and b. *by reafforestation*, forest stands established artificially on land that carried forest within the previous 50 years (or within living memory) in which the previous crop has been replaced by a new and essentially different crop. Reforestation does not include regeneration of old crops (either through natural regeneration or forest management), although some countries may have reported this as reforestation. Reforestation figures cannot be subtracted from deforestation figures to derive a "net loss" statistic because the two figures are not comparable.

Data for the FAO/UNEP assessment were collected from research institutes; correspondence with the forestry services of almost all 76 countries; visits to national forestry, land use, and survey institutions in some of the major forestry countries, and to the regional offices of FAO; photographic surveys of all or part of five countries; satellite imagery of all or part of 19 countries; and side-looking airborne radar (SLAR) surveys of four additional countries. Three countries (Burma, India, and Peru) prepared their own national reports. In many cases, data were adjusted by the FAO to fit common definitions and to correspond to a base year of 1980.

The FAO/UNEP statistics were chosen because of their international coverage, relative timeliness, and extensive documentation. Even so, the quality of the data varies considerably from country to country. Deforestation estimates were considered reliable by FAO for 33 of the 56 countries for which data collection procedures were documented.

The FAO/ECE survey relied on four types of sources: official data supplied in response to questionnaires; estimates by expert correspondents in certain countries; recent ECE and FAO publications, country reports, and official articles and estimates by the professional staff conducting the study. Most of the data refer to the period around 1980, but no attempt was made to adjust the data to a common baseline year.

For an evaluation and detailed comparison of forest statistics, see Alan Grainger, "Quantifying Changes in Forest Cover in the Humid Tropics: Overcoming Current Limitations," *Journal of World Forest Resource Management*, Vol. 1, pp. 3–23 (1984).

Table 6.2 Forest Products, 1972–83

Source: U.N. Food and Agriculture Organization, *Yearbook of Forest Products 1983* (FAO, Rome, 1985).

Total roundwood refers to all wood in the rough, whether destined for industrial uses or for use as fuelwood.

Fuelwood includes all rough wood used for cooking, heating, and power production. Wood intended for charcoal production, pit kilns, and portable ovens is included.

Industrial roundwood refers to all roundwood products other than fuelwood and charcoal: sawlogs, veneer logs, sleepers, pitprops, pulpwood, and other industrial products.

Imports are usually on a cost, insurance, freight (cif) basis. Exports are usually on a free-on-board (fob) basis. Data for imports and exports are reported in current U.S. dollars.

The FAO compiles forest products data from responses to annual questionnaires sent to national governments. Data from other sources, such as national statistical yearbooks, are also used, and in some cases FAO prepares its own estimates. The FAO revises its data using new information, so the latest figures are subject to revision.

Statistics on the production of fuelwood and charcoal are lacking for many countries. The FAO estimates fuelwood and charcoal production for these countries using population data and country-specific per-capita consumption figures. Consumption of non-coniferous fuelwood ranges from 0.0016 cubic meters per capita per year in Jordan to 0.9783 cubic meters per capita per year in Benin. Consumption estimates were also made for coniferous fuelwood. For both coniferous and non-coniferous fuelwood these per-capita, country-specific consumption estimates were multiplied by the number of people in the country to determine national totals.

Table 6.3 Extent of Desertification, Early 1980s

Source: Mabbutt, J.A., "A New Global Assessment of the Status and Trends of Desertification," *Environmental Conservation*, Vol. 11, No. 2, p. 106 (1984).

Desertification is the diminution or destruction of the biological productivity of the land

and can lead ultimately to desert-like conditions. For this table, the definition was applied only to the world's drylands: hyperarid, arid, semi-arid, and subhumid zones of low and variable rainfall. These regions are inherently vulnerable to water stress and droughts and are particularly vulnerable to deterioration resulting from unsustainable human use of the land.

Desertification is generally associated with a sequence of interactive processes: impoverishment of, and reduction in, vegetative cover; exposure of the soil surface to accelerated wind and water erosion; reduction of the soil's organic matter and nutrient content; and deterioration of the structure, moisture-holding capacity, and fertility of the soil.

The principal indicators used to assess desertification include deterioration of rangeland; deterioration of rainfed croplands, waterlogging and salinization of irrigated lands; deforestation and destruction of woody vegetation; decline in the availability and quality of surface and ground water, and encroachment and growth of sand sheets and dunes.

Generally, moderate desertification implies a loss of productivity of less than 25 percent; severe desertification causes a loss of productivity of 25 to 50 percent, and very severe desertification causes a loss of productivity of over 50 percent. The "percent desertified" used in this table is the fraction of the productive land type that is moderately to very severely desertified.

Data for this table were compiled from many sources and involve extrapolation from partial data. More than 100 countries affected by desertification received desertification questionnaires from UNEP, that requested information on land-use patterns, the status and trends of desertification, and actions taken to combat desertification. Twenty-five countries submitted extensive reports updating earlier studies conducted for the U.N. Conference on Desertification (1977). Regional assessments were prepared by U.N. regional commissions (including the U.N. Sudano-Sahelian office). Other published and unpublished works by the United Nations Educational, Scientific, and Cultural Organization, the World Meteorological Organization, FAO, UNEP, and others were used. Refer to these sources for further details on data and methods.

7. Wildlife Resources

Many national governments and other organizations have only recently begun to monitor their valuable wildlife resources (species and ecosystems) and to collect and publish the statistics needed to assess them. This edition of *World Resources* presents tables on a few national and international efforts to protect natural ecosystems, as well as data on the number of mammals threatened with extinction.

Information on protected areas, as defined by the International Union for Conservation of Nature and Natural Resources (IUCN), is shown in Table 7.1. Five categories of protected areas are included: strict nature reserves, national parks, natural monuments, wildlife sanctuaries, and protected landscapes. A few well-known examples are the Amboseli and Serengeti National Parks of Kenya and Tanzania; the Wolung Nature Reserve in China; the protected landscape of the Lake District in England; and the Great Barrier Reef Marine Park in Australia.

Not included are many local and provincial areas, areas less than 1,000 hectares in size, areas privately owned, and areas where local customs permit hunting and other consumptive uses of wildlife. The total protected area for each country is therefore greater than indicated in the tables.

However, areas that are officially designated "protected" by national authorities may not be well-protected or adequately managed in practice. Management and enforcement practices vary widely within and among countries, and many protected areas are being encroached upon by settlements and degraded by industrial pollution. Furthermore, because there is no widely accepted classification of ecological areas (terrestrial and aquatic), experts and authorities have considerable difficulty making an effective case for additional protected areas when faced with immediate demands for more land for agriculture and settlements.

Antarctica is a special case. Seven reserves have been established under the auspices of the Antarctica Treaty of 1959. However, because even tourism and scientific research can disrupt this fragile natural system, new areas are being considered for protection by the Scientific Committee for Antarctic Research and the IUCN.

Table 7.2 presents data on protected areas that are of global importance. They include Biosphere Reserves, World Heritage Sites, and Wetlands of International Significance.

Biosphere Reserves are terrestrial and coastal environments that have been internationally recognized for conservation, study, and sustained development. A major goal of the Man and the Biosphere Program of the United Nations Educational, Scientific and Cultural Organization (UNESCO) is to build a network of representative samples of the world's 194 biogeographical provinces. As of December 1985, 243 Biosphere Reserves had been established in 65 countries, covering about 100 (52 percent) of these provinces. These reserves include Mapimi Reserve in Mexico, Everglades National Park in the United States, Cévennes National Park in France, Sakaerat Reserve in Thailand, Changbai Reserve in China, Berezinsky Zapovednik in the Soviet Union, and the Tai Forest in the Ivory Coast.

Table 7.3 presents data on globally threatened mammals of Africa, the Americas, and Australia. (Comparable data from IUCN for Europe and Asia are not available, nor are global data on other vertebrates, invertebrates, and plants.) Numbers of species threatened at the national level are available for the Americas and for OECD countries. See Part II, Chapter 6, "Wildlife and Habitat," (Tables 6.3 and 6.4). The total number of mammal species that are threatened globally include those listed as endangered, vulnerable, rare, indeterminate, and insufficiently known. The table does not include species (or subspecies) that are threatened within one country but are relatively abundant in other countries. For example, the ring-tail cat *(Bassariscus sumichrasti)*, a member of the raccoon family, is now considered threatened in Costa Rica, however, since substantial populations are found in other countries of Central America, it is not included on this list.

Brazil has the largest number of species that are globally threatened. Examples of threatened mammals include the bridled nailtail wallaby (*Onychogalea fraenata*), in Australia; the gorilla (*Gorilla gorilla*), in equatorial Africa; the giant anteater (*Myrmecophaga tridactyla*), in Central and South America; and the polar bear (*Ursus maritimus*) in North America. A few threatened species, such as the polar bear, the vicuña (*Vicugna vicugna*), and the Argentine Pampas Deer (*Ozotoceros bezoarticus celer*), are responding to conservation efforts, and their populations are growing. Others, such as the Golden Lion Tamarin (*Leontopithecus rosalia*), have declining populations and it is expected that, unless individuals bred in captivity can be successfully reintroduced to the wild, this species will become extinct.

Table 7.1 MAJOR PROTECTED AREAS, 1985

	Protected Areas 1985			
	Number	Total Size (thousand hectares)	Percentage of Territory Protected 1985	Protected Area per Thousand Population 1985 (hectares)
WORLD	**3513**	**423774**	**3.2**	**88**
AFRICA	**443**	**88662**	**3.0**	**160**
Algeria	5	227	0.1	10
Angola	5	1518	1.2	173
Benin	2	844	7.6	211
Botswana	8	11644	19.9	10791
Burkina Faso	6	683	2.5	98
Burundi	0	0	0.0	0
Cameroon	15	2228	4.7	229
Cape Verde	0	0	0.0	0
Central African Rep	7	3904	6.3	1521
Chad	1	114	0.1	23
Comoros	0	0	0.0	0
Congo	10	1353	4.0	778
Djibouti	0	0	0.0	0
Egypt	1	17	0.0	0
Equatorial Guinea	0	0	0.0	0
Ethiopia	10	3028	2.7	83
Gabon	5	1673	6.5	1435
Gambia	0	0	0.0	0
Ghana	8	1175	5.1	87
Guinea	1	13	0.1	2
Guinea-Bissau	0	0	0.0	0
Ivory Coast	10	1865	5.9	190
Kenya	28	3105	5.5	151
Lesotho	1	7	0.2	4
Liberia	1	131	1.4	60
Libya	2	130	0.1	36
Madagascar	14	675	1.2	67
Malawi	9	1081	11.5	154
Mali	6	876	0.7	109
Mauritania	2	1483	1.4	785
Mauritius	3	4	2.2	4
Morocco	2	41	0.1	2
Mozambique	6	1815	2.3	129
Niger	3	372	0.3	61
Nigeria	3	868	1.0	9
Rwanda	2	262	10.5	43
Senegal	9	2177	11.3	334
Sierra Leone	1	98	1.4	27
Somalia	1	334	0.5	60
South Africa	149	5689	4.7	176
Sudan	3	1916	0.8	89
Swaziland	4	40	2.3	62
Tanzania, United Rep	15	10602	12.0	471
Togo	7	473	8.7	162
Tunisia	3	33	0.2	5
Uganda	18	1332	6.7	85
Zaire	9	8827	3.9	267
Zambia	19	6664	9.0	1000
Zimbabwe	17	2758	7.1	315
NORTH AMERICA	**422**	**161860**	**6.9**	**404**
Barbados	0	0	0.0	0
Canada	78	22949	2.5	896
Costa Rica	21	412	8.1	159
Cuba	4	24	0.2	2
Dominican Rep	5	220	4.5	35
El Salvador	0	0	0.0	0
Guatemala	2	60	0.5	7
Haiti	2	5	0.2	1
Honduras	4	423	3.8	97
Jamaica	0	0	0.0	0
Mexico	29	938	0.5	12
Nicaragua	2	17	0.1	5
Panama	6	661	8.7	303
Trinidad and Tobago	8	17	3.2	15
United States	251	64946	7.1	273
SOUTH AMERICA	**267**	**50060**	**2.9**	**186**
Argentina	29	2594	0.9	85
Bolivia	12	4708	4.3	739
Brazil	50	11894	1.4	88
Chile	64	12737	17.0	1055
Colombia	30	3959	3.8	138
Ecuador	12	2627	9.5	280
Guyana	1	12	0.1	12
Paraguay	9	1121	2.8	304
Peru	11	2408	1.9	122
Suriname	9	582	3.6	1650
Uruguay	6	29	0.2	10
Venezuela	34	7389	8.4	402

Table 7.1

	Protected Areas 1985		Percentage of Territory Protected 1985	Protected Area per Thousand Population 1985 (hectares)
	Number	Total Size (thousand hectares)		
ASIA	**790**	**52414**	**2.0**	**19**
Afghanistan	0	0	0.0	0
Bahrain	0	0	0.0	0
Bangladesh	3	32	0.2	0
Bhutan	11	950	20.2	670
Burma	0	0	0.0	0
China	63	2306	0.2	2
Cyprus	0	0	0.0	0
India	239	11149	3.7	15
Indonesia	140	13755	7.6	83
Iran	24	3056	1.9	68
Iraq	0	0	0.0	0
Israel	5	34	1.7	8
Japan	50	2196	5.9	18
Jordan	2	34	0.4	10
Kampuchea, Dem	1	11	0.1	1
Korea, Dem People's Rep	0	0	0.0	0
Korea, Rep	14	476	4.8	12
Kuwait	0	0	0.0	0
Lao People's Dem Rep	0	0	0.0	0
Lebanon	0	0	0.0	0
Malaysia	34	1559	4.7	100
Mongolia	4	4673	3.0	2459
Nepal	10	974	7.1	59
Oman	1	20	0.1	16
Pakistan	52	6537	8.4	64
Philippines	26	391	1.3	7
Qatar	0	0	0.0	0
Saudi Arabia	1	450	0.2	40
Singapore	1	2	4.3	1
Sri Lanka	37	643	9.9	39
Syrian Arab Rep	0	0	0.0	0
Thailand	45	2721	5.3	53
Turkey	15	287	0.4	6
United Arab Emirates	0	0	0.0	0
Viet Nam	12	158	0.5	3
Yemen	0	0	0.0	0
Yemen, Dem	0	0	0.0	0
EUROPE	**704**	**17239**	**3.6**	**35**
Albania	4	10	0.4	3
Austria	27	297	3.6	40
Belgium	4	12	0.4	1
Bulgaria	12	56	0.5	6
Czechoslovakia	28	1157	9.2	74
Denmark	23	126	3.0	24
Finland	33	803	2.6	165
France	37	1655	3.0	30
German Dem Rep	13	21	0.2	1
Germany, Fed Rep	45	531	2.2	9
Greece	14	63	0.5	6
Hungary	36	421	4.6	39
Ireland	3	20	0.2	6
Italy	34	517	1.8	9
Luxembourg	4	114	38.1	315
Malta	0	0	0.0	0
Netherlands	50	164	4.8	11
Norway	61	4717	12.2	1137
Poland	15	113	0.4	3
Portugal	12	381	4.2	38
Romania	9	98	0.4	4
Spain	56	1701	3.4	44
Sweden	67	1463	3.6	177
Switzerland	19	121	3.0	19
United Kingdom	57	1553	6.4	28
Yugoslavia	20	336	1.3	14
USSR	**141**	**15111**	**0.7**	**54**
OCEANIA	**739**	**38232**	**4.5**	**1540**
Australia	581	35414	4.6	2254
Fiji	2	5	0.3	8
New Zealand	147	2787	10.4	847
Papua New Guinea	2	3	0.0	1
Solomon Islands	0	0	0.0	0
ANTARCTICA	**7**	**195**	**0.0**	**NA**

Source: International Union for Conservation of Nature and Natural Resources
0 = zero or less than one-half the unit of measure; NA = not applicable
For additional information, see Sources and Technical Notes

Table 7.2 BIOSPHERE RESERVES, WORLD HERITAGE SITES,

	Biosphere Reserves 1985		Natural World Heritage Sites 1985	Wetlands of International Importance 1985	
	Number	Area (hectares)	Number	Number	Area (hectares)
WORLD	**243**	**154919316**	**63**	**329**	**19304999**
AFRICA	**36**	**11761499**	**20**	**13**	**1310548**
Algeria	0	0	1	2	8400
Angola	0	0	—	—	—
Benin	0	0	0	—	—
Botswana	0	0	—	—	—
Burkina Faso	0	0	—	—	—
Burundi	0	0	0	—	—
Cameroon	3	850000	0	—	—
Cape Verde	0	0	—	—	—
Central African Rep	2	1640200	0	—	—
Chad	0	0	—	—	—
Comoros	0	0	—	—	—
Congo	1	110000	—	—	—
Djibouti	0	0	—	—	—
Egypt	1	1000	0	—	—
Equatorial Guinea	0	0	—	—	—
Ethiopia	0	0	1	—	—
Gabon	1	15000	—	—	—
Gambia	0	0	—	—	—
Ghana	1	7770	0	—	—
Guinea	2	133300	1		—
Guinea-Bissau	0	0	—	—	—
Ivory Coast	2	1480000	3	—	—
Kenya	4	851359	—	—	—
Lesotho	0	0	—	—	—
Liberia	0	0	—	—	—
Libya	0	0	0	—	—
Madagascar	0	0	0	—	—
Malawi	0	0	1	—	—
Mali	1	771000	0	—	—
Mauritania	0	0	0	1	1173000
Mauritius	1	3594	—	—	—
Morocco	0	0	0	4	10580
Mozambique	0	0	0	—	—
Niger	0	0	0	—	—
Nigeria	1	460	0	—	—
Rwanda	1	15065	—	—	—
Senegal	3	1093756	2	3	96000
Sierra Leone	0	0	—	—	—
Somalia	0	0	—	—	—
South Africa	0	0	—	2	9968
Sudan	2	1900970	0	—	—
Swaziland	0	0	—	—	—
Tanzania, United Rep	2	2337900	3	—	—
Togo	0	0	—	—	—
Tunisia	4	32425	1	1	12600
Uganda	1	220000	—	—	—
Zaire	3	297700	4	—	—
Zambia	0	0	0	—	—
Zimbabwe	0	0	1	—	—
NORTH AMERICA	**50**	**12927433**	**19**	**17**	**10380014**
Barbados	0	0	—	—	—
Canada	2	58147	5	17	10380014
Costa Rica	1	500000	1	—	—
Cuba	1	10000	0	—	—
Dominican Rep	0	0	0	—	—
El Salvador	0	0	—	—	—
Guatemala	0	0	1	—	—
Haiti	0	0	0	—	—
Honduras	1	500000	1	—	—
Jamaica	0	0	0	—	—
Mexico	3	473200	0	—	—
Nicaragua	0	0	0	—	—
Panama	1	575000	1	—	—
Trinidad and Tobago	0	0	—	—	—
United States	41	10811086	10	—	—
SOUTH AMERICA	**20**	**10856377**	**6**	**3**	**14877**
Argentina	3	1993280	2	—	—
Bolivia	2	300000	0	—	—
Brazil	0	0	0	—	—
Chile	7	2575469	0	1	4877
Colombia	3	2514375	0	—	—
Ecuador	1	766514	2	—	—
Guyana	0	0	0	—	—
Paraguay	0	0	—	—	—
Peru	3	2506739	2	—	—
Suriname	0	0	—	1	10000
Uruguay	1	200000	—	1	X
Venezuela	0	0	—	—	—

AND WETLANDS OF INTERNATIONAL IMPORTANCE, 1985

	Biosphere Reserves 1985		World Heritage Sites 1985	Wetlands of International Importance 1985	
	Number	Area (hectares)	Number	Number of Sites	Area (hectares)
ASIA	**30**	**4598638**	**6**	**32**	**1450883**
Afghanistan	0	0	0	—	—
Bahrain	0	0	—	—	—
Bangladesh	0	0	0	—	—
Bhutan	0	0	—	—	—
Burma	0	0	—	—	—
China	3	425645	—	—	—
Cyprus	0	0	0	—	—
India	0	0	3	2	119400
Indonesia	6	1319440	—	—	—
Iran	9	2609731	0	18	1297550
Iraq	0	0	0	—	—
Israel	0	0	—	—	—
Japan	4	116000	—	2	5571
Jordan	0	0	0	1	7372
Kampuchea, Dem	0	0	—	—	—
Korea, Dem People's Rep	0	0	—	—	—
Korea, Rep	1	37430	—	—	—
Kuwait	0	0	—	—	—
Lao People's Dem Rep	0	0	—	—	—
Lebanon	0	0	0	—	—
Malaysia	0	0	—	—	—
Mongolia	0	0	—	—	—
Nepal	0	0	2	—	—
Oman	0	0	0	—	—
Pakistan	1	31355	0	9	20990
Philippines	1	23525	0	—	—
Qatar	0	0	0	—	—
Saudi Arabia	0	0	0	—	—
Singapore	0	0	—	—	—
Sri Lanka	2	9412	0	—	—
Syrian Arab Rep	0	0	0	—	—
Thailand	3	26100	—	—	—
Turkey	0	0	1	—	—
United Arab Emirates	0	0	—	—	—
Viet Nam	0	0	—	—	—
Yemen	0	0	0	—	—
Yemen, Dem	0	0	0	—	—
EUROPE	**78**	**73213585**	**7**	**224**	**1977797**
Albania	0	0	—	—	—
Austria	4	27600	—	5	X
Belgium	0	0	—	—	—
Bulgaria	17	17411	2	4	3240
Czechoslovakia	3	168892	—	—	—
Denmark	1	70000000	0	26	593372
Finland	0	0	—	11	101343
France	4	344527	1	—	—
German Dem Rep	2	3497	—	8	49600
Germany, Fed Rep	1	13100	0	20	314315
Greece	2	8840	0	11	78200
Hungary	5	128883	0	8	29450
Ireland	2	8808	—	1	110
Italy	3	33738	0	40	37292
Luxembourg	0	0	0	—	—
Malta	0	0	0	—	—
Netherlands	0	0	—	13	263185
Norway	1	1555000	0	14	17545
Poland	4	25576	1	5	7090
Portugal	1	395	0	2	30563
Romania	3	41213	—	—	—
Spain	9	424977	0	3	52392
Sweden	0	0	0	20	271075
Switzerland	1	16870	0	2	1816
United Kingdom	13	44258	0	28	89115
Yugoslavia	2	350000	3	2	18094
USSR	**17**	**36838654**	**0**	**12**	**2880100**
OCEANIA	**12**	**4723130**	**5**	**28**	**1290780**
Australia	12	4723130	5	26	1275973
Fiji	0	0	—	—	—
New Zealand	0	0	0	2	14807
Papua New Guinea	0	0	—	—	—
Solomon Islands	0	0	—	—	—
ANTARCTICA					

Sources: International Union for Conservation of Nature and Natural Resources; Man and the Biosphere Program of UNESCO.
0 = zero; X = not available; — = country not a full party to the Convention.
For additional information, see Sources and Technical Notes.

Table 7.3 MAMMALS OF AFRICA, THE AMERICAS, AND AUSTRALIA, 1985

	Total Number of Species	Number of Species Globally Threatened
AFRICA		
Algeria	97	11
Angola	275	12
Benin	187	7
Botswana	154	7
Burkina Faso	147	6
Burundi	103	6
Cameroon	297	16
Cape Verde	9	3
Central African Rep	208	7
Chad	131	11
Congo	198	11
Djibouti	22	6
Egypt	105	10
Equatorial Guinea	182	12
Ethiopia	256	16
Gabon	190	9
Gambia	108	4
Ghana	222	9
Guinea	188	10
Guinea Bissau	109	6
Ivory Coast	226	12
Kenya	308	9
Lesotho	33	2
Liberia	193	11
Libya	76	9
Malawi	192	5
Mali	136	10
Mauritania	61	10
Morocco	108	8
Mozambique	183	6
Namibia	161	10
Niger	131	9
Nigeria	274	18
Rwanda	147	7
Sao Tome	7	0
Senegal	166	10
Sierra Leone	178	10
Somalia	173	14
South Africa	279	16
Sudan	266	16
Swaziland	46	3
Tanzania	310	12
Togo	196	6
Tunisia	77	8
Uganda	311	10
Western Sahara	15	7
Zaire	409	17
Zambia	228	6
Zimbabwe	194	7
NORTH AMERICA		
Canada	163	8
Greenland (Denmark)	26	7
United States	367	25
CENTRAL AMERICA		
Belize	124	9
Costa Rica	200	10
El Salvador	135	7
Guatemala	179	9
Honduras	173	8
Mexico	440	15
Nicaragua	175	9
Panama	211	12
SOUTH AMERICA		
Argentina	272	25
Bolivia	275	24
Brazil	413	38
Chile	112	10
Colombia	330	23
Ecuador	280	20
French Guiana	152	11
Guyana	193	12
Paraguay	154	14
Peru	350	30
Suriname	188	11
Uruguay	82	7
Venezuela	293	18
AUSTRALIA	**299**	**46**

Source: International Union for Conservation of Nature and Natural Resources.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 7.1 Major Protected Areas, 1985

Sources: International Union for Conservation of Nature and Natural Resources (IUCN), Commission on National Parks and Protected Areas, *1985 United Nations List of National Parks and Protected Areas*, (IUCN, Gland, Switzerland and Cambridge, England, 1985), and unpublished data supplied by the Conservation Monitoring Center, (IUCN, Cambridge, United Kingdom, August 1985.)

The Protected Areas Data Unit of the IUCN Conservation Monitoring Center works with the Commission on National Parks and Protected Areas (one of six commissions of the International Union for Conservation of Nature and Natural Resources) to maintain a detailed listing of protected areas in all countries. Five of the ten categories of protected areas recognized by IUCN are included in the table. They are:

- *Category I. Scientific reserves and strict nature reserves.* These areas possess outstanding and representative ecosystems. The sites are generally closed to public access. Their size is determined by the area required to ensure the integrity of the site. In many of these sites, natural perturbations (e.g., insect epidemics, forest fires) are allowed to occur.
- *Category II. National parks and provincial parks.* These are relatively large areas of national or international significance that are not materially altered by humans. Access is controlled, but visitors are encouraged to use the areas for recreation and study.
- *Category III. Natural monuments and natural landmarks.* These areas contain unique geological formations, special animals or plants, or unusual habitat. Areas vary in size. Access is usually restricted.
- *Category IV. Managed nature reserves and wildlife sanctuaries.* These sites are designated mainly to provide protection for particular uses such as conservation of a nationally significant plant or animal species. Some areas may require management. For example, a particular grassland or heath community may be protected and perpetuated best by allowing livestock grazing. The sizes of the areas vary. Public access is restricted to scientific and educational purposes.
- *Category V. Protected landscapes and seascapes.* Areas so designated may be entirely natural, without any human artifacts, or may include cultural landscapes. Protected landscapes may be coastlines, lake shores, hilly or mountainous terrain along scenic highways, etc. Areas vary in size, and public control depends on the use of the area.

Each area is greater than 1,000 hectares in size. Islands less than 1,000 hectares but greater than 100 hectares are also included.

Data for Categories VI, VII, and VIII are less complete and therefore omitted. Resources Reserves (Category VI) are relatively isolated, uninhabited areas that have been little studied. Anthropological Reserves (Category VII) are natural areas in which humans are an integral component. Management is oriented toward the maintenance of habitat for traditional societies. Multiple Use Management Areas (Category VIII) are large areas in which the principal goal is to manage renewable resources such as timber, game, and recreation potential on a sustained basis. Biosphere Reserves (Category IX) and World Heritage Sites—natural areas—(Category X) are shown in Table 7.2.

Continental and world totals include information for countries not included in the table because they have a population of less than 240,000. The Bahamas, for example, have four protected areas totalling 122,540 hectares, and Iceland has 21 protected areas totalling 789,420 hectares. Data for the Soviet Union include protected areas in the Ukraine and Byelorussia. Data for China include Taiwan. Greenland data are included in the subtotal for North America; they are excluded from Denmark.

Table 7.2 Biosphere Reserves, World Heritage Sites, and Wetlands of International Importance, 1985

Sources: Biosphere Reserves and World Heritage Sites: Man and the Biosphere Program, UNESCO *List of Biosphere Reserves* (UNESCO, Paris, December 1984); World Heritage Secretariat UNESCO, "Properties Inscribed on the World Heritage List by Decision of the World Heritage Committee," (UNESCO, Paris, December 1985); International Union for Conservation of Nature and Natural Resources (IUCN), Commission on National Parks and Protected Areas, *The 1985 United Nations List of National Parks and Protected Areas* (IUCN, Gland, Switzerland, 1985); and Conservation Monitoring Center, IUCN (IUCN, unpublished data, Cambridge, England, August 1985). Wetlands of International Importance: Conservation Monitoring Center, IUCN (IUCN, unpublished list, Cambridge, England, August 1985).

Biosphere Reserves are an international network of protected areas approved by the International Coordinating Council of UNESCO's Man and the Biosphere (MAB) Program. Each area must contain an ecosystem that is typical of a biogeographical province in terms of diversity, naturalness, and effectiveness as a conservation unit. Each Biosphere Reserve must include a minimally disturbed, defined core area available for conservation and research. Around the core area there must be a transition area, which may contain geographically defined areas for specific activities such as experimental research on the functioning of ecosystems, rehabilitation of modified or degraded ecosystems, or traditional uses.

World Heritage Sites are structures or natural areas of "outstanding universal value." (Only natural sites are included in the table.) Sites are nominated by any of the countries party to the World Heritage Convention and are reviewed for the convention committee by IUCN. To be accepted, a natural site must contain an example of a major stage of the earth's evolutionary history; a significant ongoing geological process; a unique or superlative natural phenomenon, formation or feature; or a habitat for endangered or rare species of plants and animals required for the survival of the species.

Areas that are designated Biosphere Reserves, World Heritage Sites, or Wetlands of International Importance, and are also national parks, natural monuments, etc. are listed under both headings.

In the category of Biosphere Reserves, Greenland is included under Denmark and Ukraine and Byelorussia are included in the USSR figure. The United States and Canada share one World Heritage Site (Kluane-Wrangell/St. Elias National Park), which is listed for both countries.

Wetlands of International Importance are specific wetlands so designated by any of the 38 countries that have ratified the Convention on Wetlands of International Importance Especially as Waterfowl Habitat. The collection of wetland data is carried out by IUCN with the assistance of the International Waterfowl Research Bureau (IWRB), the International Council for Bird Preservation (ICBP), and the United Nations Environment Program (UNEP). The data are maintained by the Conservation Monitoring Center at Cambridge, England.

In the category of Wetlands of International Importance, the Netherlands includes the Netherlands Antilles. Iceland, which has one Wetland of International Importance (20,000 hectares), is included in the European and world totals.

Table 7.3 Mammals of Africa, the Americas, and Australia, 1985

Sources: International Union for Conservation of Nature and Natural Resources (IUCN), *The IUCN Mammal Red Data Book, Part 1.* (IUCN, Gland, Switzerland, 1982), and Conservation Monitoring Center, IUCN (IUCN, unpublished data, Cambridge, England, October 1985).

The Species Conservation Monitoring Unit of IUCN maintains a data base of animals that are threatened in the wild. The following six categories are used to classify mammals:

1. *Endangered.* "Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating." Included are taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction. Also included are taxa that are possibly already extinct but have definitely been seen in the wild in the past 50 years.
2. *Vulnerable.* "Taxa believed likely to move into the Endangered category in the near future if the causal factors continue operating." Included are taxa of which most or all the populations are decreasing because

of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security has not yet been assured; and taxa with populations that are still abundant but are under threat from severe adverse factors throughout their range.

3. *Rare.* "Taxa with small world populations that are not at present Endangered or Vulnerable, but are at risk." These taxa are usually localized within restricted geographical areas or habitats or are thinly scattered over a more extensive range.
4. *Indeterminate.* "Taxa known to be Endangered, Vulnerable, or Rare but where there is not enough information to say which of the three categories is appropriate."
5. *Out of Danger.* "Taxa formerly included in one of the above categories, but which are now considered relatively secure because effective conservation measures have been taken or the previous threat to their survival has been removed."
6. *Insufficiently Known.* "Taxa that are suspected but not definitely known to belong to any of the above categories because of lack of information."

In practice, the Endangered and Vulnerable categories may include taxa whose populations are beginning to recover as a result of remedial action but whose recovery is insufficient to justify their transfer to another category.

The total number of mammal species that are threatened globally include Endangered, Vulnerable, Rare, Indeterminate, and Insufficiently Known species.

The total number of mammal species includes species that were introduced to a country, but the number of threatened species excludes introduced species.

The data exclude cetaceans (whales and porpoises). The IUCN notes that the total number of the bat, insectivore, and rodent species may be underreported.

Although the listing of globally threatened species is based on the judgment of many experts working in the field and has taken years to compile, it is under continuous revision as new species are discovered and as more mammals become threatened.

8. Energy and Minerals

The tables in this section focus on the production and consumption of commercial energy and minerals. One table presents data on nuclear generation and radioactive wastes. Future editions of *World Resources* will include data on hydropower, coal, petroleum, and renewable sources of energy.

After the petroleum price increases of 1974, a number of countries greatly increased their energy production. Congo, for example, increased energy production from 1 to 229 petajoules: a 229-fold increase in 14 years. Cameroon, Ivory Coast, Guatemala, Ecuador, Malaysia, and Norway reported 10-fold increases during the same period.

The consumption figures reflect a different pattern. Many non-industrialized, petroleum-rich countries greatly increased domestic consumption. Saudi Arabia's consumption increased by a factor of 11; Libya's, by 13. In contrast, many industrialized nations reduced consumption. The United States' consumption declined by 2 percent over this period; consumption per constant dollar of Gross National Product declined by 30 percent.

Imports as a percentage of consumption is an indicator of energy self-sufficiency. The numerator can be positive (a net importer of energy) or negative (a net exporter of energy); the denominator (consumption) is always positive. The ratio, therefore, can be either positive or negative. Norway, for example, imported 61 percent of its energy in 1970. By 1983, Norway exported the equivalent of three times its consumption. Oman exported 235 times its consumption in 1970; 35 times its consumption in 1983. This ratio should not normally exceed a positive 100 percent. A country with a figure greater than 100 percent may have imported more energy in a given year than was consumed in that year, or neglected to account for exports of refined products produced with imported fuels, or misreported its consumption.

There is no single best source of international energy data. The U.N. Statistical Office, the source for Tables 8.1 and 8.2, compiles data from questionnaires sent to all national governments. Other information is gathered from national statistical yearbooks, trade literature, and special energy surveys. The U.N. Statistical Office also gets price data from OECD and the U.S. Department of Energy, which in turn gets much of its information from special reports and country statistical yearbooks. The major petroleum companies (British Petroleum, Texaco, Royal Dutch/Shell, and others) also maintain extensive energy data bases. Despite this large and growing effort, there are serious gaps in energy data. Patterns of energy consumption broken down by commercial, residential, industrial, and transport use are virtually non-existent outside the industrialized countries, and data for even these countries have undergone extensive revisions in the past few years.

The most difficult problem in data collection is gathering data on renewable energy sources, particularly fuelwood and crop and animal residues used for cooking and heating in developing countries. Currently, these data are estimated on the basis of the amount of wood consumed by a family or household unit during the year, multiplied by the number of such units in a country, and increased from year to year based on the rate of population growth. These data have been included only in calculating total energy requirements in Table 8.2. For countries such as Tanzania, Zaire, Nepal, Bangladesh, and even Nigeria (a major oil producer and consumer), the non-commercial fuels are a major component of national energy use. Libya, rich in petroleum and poor in biomass resources, reports very little non-commercial fuel use.

For many countries the production of minerals is as important to their economies as the production of energy. The U.S. Bureau of Mines maintains an international data base for more than 30 metals, 28 non-metals, and 7 mineral fuels. The three minerals, ten ores, and two primary metals listed in Table 8.4 were selected on the basis of importance to national economies and international trade. While world mineral production is dominated by a few major producers, many of these are small countries. Morocco, Tunisia, Jordan, Togo, Nauru, Senegal, and Christmas Island are all major producers of phosphate rock, the principal source of phosphate fertilizers.

Consumption of materials, shown in Table 8.5, is dominated by the major industrialized countries. Only data for metals consumption are available on a country-by-country basis and over time. Metric tons of metal consumed per million dollars of GNP is an important indicator of the intensity of a metal's use.

Table 8.1 PRODUCTION OF COMMERCIAL ENERGY, 1970–83

	Total		Solid		Liquid		Gaseous		Primary Electricity	
	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970
WORLD	**262856**	**27**	**79415**	**26**	**118483**	**18**	**54451**	**42**	**10508**	**133**
AFRICA	**14570**	**2**	**3224**	**106**	**9944**	**-20**	**1210**	**1471**	**193**	**114**
Algeria	2493	17	0	0	1976	4	516	706	1	-50
Angola	362	65	X	X	354	64	4	100	5	150
Benin	X	X	X	X	X	X	X	X	X	X
Botswana	X	X	X	X	X	X	X	X	X	X
Burkina Faso	X	X	X	X	X	X	X	X	X	X
Burundi	0	X	0	X	0	X	0	X	0	X
Cameroon	245	6025	X	X	239	X	X	X	6	50
Cape Verde	X	X	X	X	X	X	X	X	X	X
Central African Rep	0	0	0	0	0	0	0	0	0	0
Chad	X	X	X	X	X	X	X	X	X	X
Comoros	X	X	X	X	X	X	X	X	X	X
Congo	229	22800	X	X	229	22800	0	0	1	NM
Djibouti	X	X	X	X	X	X	X	X	X	X
Egypt	1655	130	X	X	1553	122	59	1867	43	153
Equatorial Guinea	0	0	0	0	0	0	0	0	0	0
Ethiopia	2	100	X	X	X	X	X	X	2	100
Gabon	344	48	X	X	337	46	6	500	1	NM
Gambia	X	X	X	X	X	X	X	X	X	X
Ghana	12	20	X	X	3	X	X	X	9	-10
Guinea	0	X	0	0	0	0	0	0	0	0
Guinea Bissau	X	X	X	X	X	X	X	X	X	X
Ivory Coast	56	5500	X	X	49	X	0	X	6	500
Kenya	6	500	X	X	X	X	X	X	6	500
Lesotho	X	X	X	X	X	X	X	X	X	X
Liberia	1	0	X	X	X	X	X	X	X	X
Libya	2694	-60	X	X	2310	-66	384	NM	X	X
Madagascar	1	NM	X	X	X	X	X	X	1	NM
Malawi	2	NM	X	X	X	X	X	X	2	NM
Mali	0	0	0	0	0	0	0	0	0	0
Mauritania	X	X	X	X	X	X	X	X	X	X
Mauritius	0	0	0	0	0	0	0	0	0	0
Morocco	30	43	24	85	1	-50	3	50	2	-60
Mozambique	33	200	11	10	X	X	X	X	22	2100
Niger	1	X	1	X	X	X	X	X	X	X
Nigeria	2836	22	1	-50	2606	13	220	5400	9	80
Rwanda	1	NM	X	X	X	X	0	0	1	NM
Senegal	X	X	X	X	X	X	X	X	X	X
Sierra Leone	X	X	X	X	X	X	X	X	X	X
Somalia	X	X	X	X	X	X	X	X	X	X
South Africa	3103	118	3101	118	X	X	X	X	3	NM
Sudan	2	NM	X	X	X	X	X	X	2	NM
Swaziland	X	X	X	X	X	X	X	X	X	X
Tanzania, United Rep	2	100	0	0	X	X	X	X	2	100
Togo	0	0	0	0	0	0	0	0	0	0
Tunisia	255	44	X	X	238	-34	18	NM	0	0
Uganda	2	-33	X	X	X	X	X	X	2	-33
Zaire	68	386	4	33	49	X	X	X	15	36
Zambia	47	161	11	-27	X	X	X	X	36	1700
Zimbabwe	84	-31	70	-32	X	X	X	X	13	32
NORTH AMERICA	**72233**	**4**	**18388**	**19**	**30527**	**13**	**19789**	**-22**	**3528**	**118**
Barbados	3	NM	X	X	2	NM	X	X	X	X
Canada	8236	37	1061	196	3299	11	2740	30	1136	100
Costa Rica	9	200	X	X	X	X	X	X	9	200
Cuba	32	357	X	X	32	357	0	X	0	0
Dominican Rep	3	NM	X	X	X	X	X	X	3	NM
El Salvador	5	150	X	X	X	X	X	X	5	150
Guatemala	27	2600	X	X	26	X	X	X	1	0
Haiti	1	X	X	X	X	X	X	X	1	X
Honduras	3	200	X	X	X	X	X	X	3	200
Jamaica	1	NM	X	X	X	X	0	0	1	NM
Mexico	7615	383	163	163	6324	526	1048	132	80	48
Nicaragua	2	100	X	X	X	X	X	X	2	100
Panama	3	200	X	X	X	X	X	X	3	200
Trinidad and Tobago	472	24	X	X	352	14	120	64	X	X
United States	55820	-9	17164	14	20493	-10	15880	-31	2283	132
SOUTH AMERICA	**10088**	**-12**	**362**	**96**	**7356**	**-29**	**1513**	**112**	**857**	**276**
Argentina	1664	52	12	-20	1117	29	457	119	79	1217
Bolivia	144	177	X	X	51	6	88	8700	4	100
Brazil	1473	169	141	147	721	110	65	2067	546	279
Chile	191	7	29	-28	93	24	37	-23	32	100
Colombia	770	21	176	167	343	-31	181	229	71	223
Ecuador	521	4635	X	X	513	5600	1	0	6	500
Guyana	0	X	0	X	0	X	0	X	0	X
Paraguay	3	00	X	X	X	X	X	X	3	200
Peru	431	129	2	-60	362	135	40	150	26	86
Suriname	4	0	X	X	1	NM	X	X	3	-25
Uruguay	26	550	X	X	X	X	X	X	26	550
Venezuela	4862	-44	1	0	4155	-50	644	69	61	307

Table 8.1

	Total		Solid		Liquid		Gaseous		Primary Electricity	
	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970	1983 (peta-joules)	Percent Change Over 1970
ASIA	**61210**	**30**	**20890**	**81**	**35076**	**4**	**3625**	**220**	**1619**	**171**
Afghanistan	107	6	5	0	0	0	99	4	3	200
Bahrain	226	28	X	X	100	-39	126	800	X	X
Bangladesh	82	X	X	X	0	X	79	X	2	X
Bhutan	X	X	X	X	X	X	X	X	X	X
Burma	88	132	1	NM	64	88	19	850	4	300
China	20005	125	14698	98	4520	246	475	324	311	320
Cyprus	X	X	X	X	X	X	X	X	X	X
India	4683	136	3309	110	1074	270	107	463	194	94
Indonesia	3521	88	14	180	2811	55	690	1368	5	25
Iran	5591	-35	23	44	5280	-35	264	-42	23	283
Iraq	2024	-38	X	X	2005	-38	17	45	2	X
Israel	3	-99	X	X	1	-100	2	-60	X	X
Japan	1284	-14	474	55	19	-44	90	-13	702	129
Jordan	X	X	X	X	X	X	X	X	X	X
Kampuchea, Dem	0	0	0	0	0	0	0	0	0	0
Korea, Dem Peoples Rep	1401	79	1307	77	X	X	X	X	94	129
Korea, Rep	407	46	365	33	X	X	X	X	42	950
Kuwait	2460	-63	X	X	2370	-63	90	13	X	X
Lao Peoples Dem Rep	4	NM	0	0	X	X	X	X	4	NM
Lebanon	2	-33	X	X	X	X	X	X	2	-33
Malaysia	827	1780	X	X	808	2084	13	333	5	25
Mongolia	52	148	52	148	X	X	X	X	X	X
Nepal	1	NM	X	X	X	X	X	X	1	NM
Oman	796	13	X	X	796	13	X	X	X	X
Pakistan	420	158	38	3	25	25	319	232	38	245
Philippines	77	863	20	1900	31	NM	X	X	25	213
Qatar	860	10	X	X	649	12	210	438	X	X
Saudi Arabia	11293	39	X	X	11243	38	50	NM	X	X
Singapore	X	X	X	X	X	X	X	X	X	X
Sri Lanka	4	33	X	X	X	X	X	X	4	33
Syrian Arab Rep	414	129	X	X	399	120	3	NM	12	NM
Thailand	102	827	22	450	8	NM	57	NM	15	150
Turkey	453	29	318	68	94	-38	0	X	41	273
United Arab Emirates	2939	82	X	X	2396	49	542	5922	X	X
Viet Nam	182	102	176	100	X	X	X	X	6	200
Yemen	X	X	X	X	X	X	X	X	X	X
Yemen, Dem	X	X	X	X	X	X	X	X	X	X
EUROPE	**40004**	**50**	**19230**	**-1**	**8417**	**415**	**9127**	**114**	**3230**	**127**
Albania	198	154	25	178	149	137	16	300	8	300
Austria	253	-23	40	-26	54	-55	49	-36	110	43
Belgium	293	-13	201	-40	X	X	1	-50	91	9000
Bulgaria	552	17	478	10	13	-7	4	-76	56	600
Czechoslovakia	1983	6	1922	6	4	-56	20	-46	36	177
Denmark	92	9100	0	-100	92	NM	X	X	0	0
Finland	120	243	11	1000	X	X	X	X	108	218
France	1671	-6	592	-49	100	-21	231	-15	748	228
German Dem Rep	2688	13	2491	6	3	25	145	625	50	733
Germany, Fed Rep	4624	-9	3509	-17	175	-46	635	38	306	256
Greece	231	285	167	234	53	X	3	X	8	-20
Hungary	656	8	280	-30	118	34	249	118	10	NM
Ireland	126	147	39	-20	X	X	83	X	4	33
Italy	809	7	16	-22	101	58	501	1	190	12
Luxembourg	2	-33	X	X	X	X	X	X	2	-33
Malta	X	X	X	X	X	X	X	X	X	X
Netherlands	3215	143	0	-100	511	523	2691	141	13	1200
Norway	2734	1148	15	15	1305	NM	1032	NM	382	85
Poland	5010	31	4820	33	11	-42	166	-11	12	71
Portugal	34	17	5	-38	X	X	X	X	29	38
Romania	2707	42	584	80	518	-12	1570	60	36	260
Spain	812	96	554	83	127	2017	0	-100	132	27
Sweden	381	152	0	-100	1	NM	X	X	380	153
Switzerland	183	59	X	X	X	X	X	X	183	59
United Kingdom	9633	127	2896	-21	4906	69986	1628	274	203	78
Yugoslavia	982	56	584	41	176	43	105	169	117	121
USSR	**60535**	**70**	**14630**	**9**	**26311**	**75**	**18638**	**179**	**957**	**107**
OCEANIA	**4216**	**127**	**2692**	**99**	**852**	**133**	**549**	**815**	**124**	**57**
Australia	3969	127	2636	103	823	127	463	727	47	42
Fiji	0	X	0	X	0	X	0	X	0	X
New Zealand	245	127	56	-2	29	1350	85	2025	75	67
Papua New Guinea	1	NM	X	X	X	X	X	X	1	NM
Solomon Islands	X	X	X	X	X	X	X	X	X	X
ANTARCTICA										

Source: U.N. Statistical Office.
0 = zero or less than one-half the unit of measure; X = not available; NM = not meaningful.
For additional information, see Sources and Technical Notes.

Table 8.2 CONSUMPTION OF COMMERCIAL ENERGY AND TOTAL

	Total		Consumption Per Capita		Consumption Per Constant (1975) $US of GNP		Imports as Percentage of Consumption		Total Requirements	
	1983 (peta-joules)	Percent Change Over 1970	1983 (giga-joules)	Percent Change Over 1970	1983 (mega-joules)	Percent Change Over 1970	1983	1970	1983 (peta-joules)	Percent Change Over 1970
WORLD	**249813**	**32**	**53**	**4**					**292650**	**38**
AFRICA	**6368**	**114**	**12**	**47**			**-121**	**-376**	**11109**	**81**
Algeria	376	154	18	70	15878	20	-501	-1356	392	139
Angola	31	19	4	-20	12310	99	-1006	-731	119	31
Benin	5	25	1	-10	6428	-24	120	100	44	47
Botswana	X	X	X	X	X	X	X	X	X	X
Burkina Faso	6	200	1	130	7307	111	100	100	75	50
Burundi	2	100	0	58	3576	41	100	100	36	33
Cameroon	120	823	13	578	26499	341	-88	69	213	154
Cape Verde	1	NM	3	NM	9662	X	100	NM	1	0
Central African Rep	3	0	1	-23	7782	-13	100	100	28	33
Chad	3	50	1	14	11472	176	100	100	78	34
Comoros	1	NM	2	NM	11710	X	100	NM	1	NM
Congo	5	0	3	-27	3729	-63	-4480	80	22	22
Djibouti	6	500	22	243	X	X	117	100	6	500
Egypt	759	199	17	121	27571	20	-104	-180	895	179
Equatorial Guinea	1	0	3	-22	X	X	100	100	5	25
Ethiopia	25	32	1	-3	7403	-10	100	116	307	33
Gabon	32	146	28	107	23732	81	-953	-1669	47	96
Gambia	2	100	3	52	14837	22	100	100	10	43
Ghana	35	-17	3	-43	8684	-6	89	81	128	10
Guinea	13	18	3	-10	9880	-15	92	100	43	30
Guinea-Bissau	1	0	1	-39	5225	-21	100	100	5	25
Ivory Coast	53	66	6	0	11022	-5	8	103	141	83
Kenya	53	56	3	-7	11731	-32	106	112	371	83
Lesotho	X	X	X	X	X	X	X	X	X	X
Liberia	22	16	11	-23	32150	-10	105	-116	64	28
Libya	560	1336	168	753	39774	1408	-362	-17362	565	1214
Madagascar	16	23	2	-13	9192	21	125	92	74	-16
Malawi	9	50	1	3	10912	-24	78	83	140	211
Mali	6	100	1	50	7086	27	100	100	48	45
Mauritania	9	50	5	5	15820	16	100	100	9	50
Mauritius	8	0	8	-16	9070	-45	100	100	26	8
Morocco	195	132	9	61	15128	27	93	83	211	109
Mozambique	37	12	3	-31	12162	34	19	70	226	85
Niger	10	233	2	139	10910	163	90	100	43	65
Nigeria	498	523	6	300	14527	321	-465	-2793	1287	114
Rwanda	3	200	1	96	3708	62	100	100	53	23
Senegal	29	93	5	25	12701	39	103	107	66	50
Sierra Leone	7	-30	2	-43	10229	-43	171	120	85	31
Somalia	16	433	3	182	19935	294	106	100	66	113
South Africa	2927	75	95	30	70077	22	-9	16	3068	71
Sudan	47	-23	2	-48	7638	-55	106	110	418	35
Swaziland	X	X	X	X	X	X	X	X	X	X
Tanzania, United Rep	25	18	1	-24	8921	-16	104	109	412	51
Togo	16	300	6	193	24521	210	63	100	22	214
Tunisia	127	195	18	120	19394	29	-94	-293	152	145
Uganda	10	-50	1	-66	X	X	80	90	257	32
Zaire	62	44	2	0	17768	29	-8	70	380	42
Zambia	65	38	10	-7	27328	17	26	64	237	166
Zimbabwe	113	-12	14	-43	26965	-45	26	5	207	-10
NORTH AMERICA	**76120**	**4**	**195**	**-15**			**7**	**7**	**86204**	**11**
Barbados	9	50	35	38	19251	9	67	117	12	20
Canada	6993	26	280	8	37196	-15	-18	-9	9697	40
Costa Rica	39	105	16	44	18771	42	82	84	79	80
Cuba	402	61	41	39	X	X	102	100	568	24
Dominican Rep	90	125	15	62	18793	7	104	100	135	96
El Salvador	28	40	5	-4	17759	21	89	95	90	58
Guatemala	47	57	6	6	10436	-5	47	100	129	61
Haiti	10	100	2	47	11312	39	90	100	65	41
Honduras	27	50	7	-3	18242	-1	93	100	81	69
Jamaica	88	33	39	10	36979	40	103	103	96	26
Mexico	3821	145	51	67	32356	32	-96	1	4216	130
Nicaragua	26	37	9	-8	19363	18	104	95	63	54
Panama	44	26	21	-8	17097	-31	102	114	73	43
Trinidad and Tobago	187	42	171	33	52972	-12	-60	-184	189	37
United States	63738	-2	273	-14	33381	-30	13	7	70131	4
SOUTH AMERICA	**7226**	**73**	**28**	**28**			**-26**	**-162**	**12107**	**82**
Argentina	1492	34	50	9	40104	23	0	10	1782	46
Bolivia	61	110	10	51	28931	80	-128	-76	86	95
Brazil	2511	106	19	52	16006	-2	59	61	6091	101
Chile	311	-2	27	-21	36787	-8	39	44	441	10
Colombia	733	98	27	49	42783	11	0	-67	1069	97
Ecuador	170	247	19	135	29995	51	-176	80	242	169
Guyana	22	0	24	-23	58063	-2	100	100	29	-3
Paraguay	20	100	6	32	7759	-17	90	100	73	66
Peru	345	47	18	4	23349	21	-20	20	481	44
Suriname	26	4	74	10	40454	-37	88	88	34	-3
Uruguay	61	-16	21	-21	16303	-26	66	107	150	60
Venezuela	1468	104	85	30	49165	42	-212	-1070	1626	111

REQUIREMENTS, 1970–83

Table 8.2

	Total		Consumption Per Capita		Consumption Per Constant (1975) $US of GNP		Imports as Percentage of Consumption		Total Requirements	
	1983 (peta-joules)	Percent Change Over 1970	1983 (giga-joules)	Percent Change Over 1970	1983 (mega-joules)	Percent Change Over 1970	1983	1970	1983 (peta-joules)	Percent Change Over 1970
ASIA	**49927**	**89**	**18**	**45**			**-16**	**-69**	**61296**	**81**
Afghanistan	28	56	2	36	12438	15	-286	-456	85	52
Bahrain	141	729	355	360	X	X	-9	-588	141	729
Bangladesh	33	X	0	X	1553	X	197	X	447	X
Bhutan	X	X	0	X	X	X	X	X	29	26
Burma	73	55	2	13	12768	-16	4	36	255	47
China	18438	118	18	74	71644	1	-5	-1	20757	109
Cyprus	36	64	55	55	27454	-19	103	100	36	64
India	4961	122	7	67	41993	38	12	19	7704	85
Indonesia	1121	176	7	108	23265	18	-197	-345	2285	75
Iran	1388	74	33	17	X	X	-289	-975	1447	75
Iraq	270	62	18	3	X	X	-634	-1855	276	64
Israel	298	60	72	15	18595	-9	109	6	298	59
Japan	11836	21	100	6	16720	-32	94	93	13487	28
Jordan	88	389	27	246	37584	78	113	111	88	389
Kampuchea, Dem	1	-92	0	-92	X	X	0	133	46	-16
Korea, Dem People's Rep	1532	84	80	33	X	X	8	6	1806	86
Korea, Rep	1694	177	43	122	46403	5	87	62	1861	176
Kuwait	248	134	153	8	13210	25	-804	-5943	248	134
Lao People's Dem Rep	9	13	2	-19	X	X	44	100	53	56
Lebanon	57	16	22	9	X	X	96	94	65	8
Malaysia	390	119	26	60	24741	-12	-105	108	476	101
Mongolia	83	159	46	80	X	X	37	34	97	120
Nepal	7	40	0	2	3562	2	86	80	148	38
Oman	22	633	19	324	7890	247	-3518	-23467	22	633
Pakistan	637	97	7	35	33844	1	39	55	936	649
Philippines	478	63	9	17	20966	-18	90	109	866	56
Qatar	232	440	826	113	132534	478	-270	-1712	232	440
Saudi Arabia	1097	1306	105	675	19753	339	-903	-10085	1097	1306
Singapore	392	409	156	321	36654	72	190	125	392	409
Sri Lanka	62	38	4	9	14294	-22	110	120	146	32
Syrian Arab Rep	267	287	27	147	30585	33	-32	-146	296	329
Thailand	511	161	10	91	21537	19	81	104	952	100
Turkey	1039	111	22	56	21926	14	64	33	1422	80
United Arab Emirates	673	4106	563	684	37688	X	-342	-9994	673	4106
Viet Nam	210	-43	4	-58	X	X	14	76	431	-18
Yemen	36	1700	6	1297	21183	477	97	100	36	1700
Yemen, Dem	49	345	24	232	79662	X	104	318	52	300
EUROPE	**59784**	**19**	**122**	**11**			**36**	**54**	**68019**	**25**
Albania	107	182	37	106	X	X	4	-5	141	139
Austria	783	10	105	9	16939	-26	66	59	1054	16
Belgium	1432	-10	145	-12	19939	-34	91	90	1651	4
Bulgaria	1471	57	161	46	X	X	67	50	1618	67
Czechoslovakia	2841	25	183	16	X	X	35	20	2941	27
Denmark	650	-17	126	-21	14913	-35	76	104	653	-17
Finland	633	15	131	10	18829	-22	88	104	916	30
France	6101	7	112	0	14858	-27	76	79	7948	25
German Dem Rep	3569	16	214	19	X	X	29	22	3693	20
Germany, Fed Rep	9954	8	162	7	19818	-18	51	51	10712	13
Greece	628	120	64	97	23891	41	72	87	666	100
Hungary	1167	37	108	31	85809	-36	53	34	1218	39
Ireland	328	47	93	24	34666	6	61	80	342	45
Italy	5060	22	89	15	22122	-9	88	94	5549	21
Luxembourg	112	-34	308	-38	29089	-65	99	98	118	-33
Malta	13	44	34	25	15359	-49	100	100	13	44
Netherlands	2693	54	187	39	27758	19	-13	51	2723	55
Norway	696	35	169	26	19428	-15	-293	61	1595	59
Poland	4731	39	128	23	X	X	-3	-11	4786	39
Portugal	388	107	39	80	20675	32	101	92	460	89
Romania	2972	66	131	49	88195	X	13	-2	3100	66
Spain	2398	65	62	45	20253	11	75	77	2718	55
Sweden	1137	-16	137	-19	14776	-31	72	94	2219	27
Switzerland	693	17	110	16	11070	1	74	85	1129	30
United Kingdom	7638	-4	137	-4	29167	-23	-26	53	8114	-1
Yugoslavia	1550	84	68	64	38260	5	40	30	1862	80
USSR	**47230**	**61**	**173**	**43**	**X**	**X**	**-21**	**-15**	**50277**	**61**
OCEANIA	**3159**	**52**	**131**	**22**			**-30**	**14**	**3636**	**52**
Australia	2697	52	176	24	23703	6	-43	5	2929	52
Fiji	9	29	14	1	10964	-23	100	86	17	6
New Zealand	342	49	106	30	24253	15	31	54	518	52
Papua New Guinea	27	145	8	69	19327	90	96	91	84	62
Solomon Islands	2	100	8	28	20725	X	100	100	4	100
ANTARCTICA										

Source: U.N. Statistical Office.
0 = zero or less than one-half the unit of measure; X = not available; NM = not meaningful.
For additional information, see Sources and Technical Notes.

Table 8.3 NUCLEAR POWER AND WASTE GENERATION, 1970–84

	Number of Operable Reactors		Installed Capacity (GWe)		Nuclear as Percent of Total Electricity Generation		Spent Fuel Inventories (cumulative metric tons of heavy metal)	
	1970	1984	1970	1984	1973	1984	1970	1984
WORLD TOTAL	**80**	**345**	**16.8**	**226.6**				
MARKET ECONOMIES	**65**	**285**	**15.2**	**196.7**			**6405**	**56654**
Europe	**44**	**133**	**8.5**	**84.4**			**6060**	**34236**
Belgium	1	5	0.0	3.5	0	51		
Finland	0	4	0.0	2.3	0	42		
France	5	41	1.6	33.3	8	59		
Germany, Fed. Rep.	4	16	0.9	16.1	4	28		
Italy	3	3	0.6	1.3	2	4		
Netherlands	1	2	0.1	0.5	2	6		
Spain	1	7	0.2	4.8	8	19		
Sweden	1	11	0.0	8.4	3	41		
Switzerland	1	5	0.4	2.9	16	37		
United Kingdom	27	38	4.8	10.7	10	17		
Yugoslavia	0	1	0.0	0.6	0	6		
North America	**16**	**103**	**5.4**	**81.2**			**331**	**17745**
Canada	1	17	0.2	10.0	6	12	96	6363
United States	15	86	5.2	71.2	4	13	235	11382
Far East	**3**	**39**	**0.8**	**27.6**			**14**	**3610**
Japan	3	31	0.8	21.8	2	23		
Korea, Rep.	0	3	0.0	1.8	0	22		
Taiwan	0	5	0.0	4.0	0	48		
Other	**2**	**10**	**0.4**	**3.5**			**0**	**1063**
Argentina	0	2	0.0	0.9	0	11		
Brazil	0	1	0.0	0.6	0	0		
India	2	5	0.4	1.0	4	3		
Pakistan	0	1	0.0	0.1	0	4		
South Africa	0	1	0.0	0.9	0	0		
NON-MARKET ECONOMIES	**15**	**60**	**1.6**	**29.9**			**X**	**X**
Bulgaria	0	4	0.0	1.8	0	32		
Czechoslovakia	0	3	0.0	1.3	0	8		
German Dem. Rep.	0	5	0.0	1.8	0	12		
Hungary	0	2	0.0	0.9	0	10		
USSR	15	46	1.6	24.1	1	8		

Sources: U.S. Department of Energy; OECD; *Nucleonics Week*; *Nuclear Engineering International*.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 8.4 PRODUCTION OF SELECTED MATERIALS, 1965–83

	Annual Production (thousand metric tons)				
	1965	1970	1975	1980	1983
ANTIMONY					
Bolivia	10	12	12	15	11
China	15	12	12	10	10
USSR	6	7	8	8	9
South Africa	13	17	16	13	6
Mexico	4	4	3	2	2
Yugoslavia	3	2	2	2	1
Australia	1	1	2	1	1
Thailand	1	2	3	3	1
Turkey	4	3	4	1	1
Morocco	2	2	1	1	1
Czechoslovakia	1	1	1	1	0
Italy	0	1	1	1	X
Canada	1	0	2	2	X
World Total	**63**	**70**	**70**	**64**	**53**
Major Producers as Percent of World Total	**96**	**92**	**94**	**95**	**83**
BAUXITE					
Australia	1186	9256	21003	27178	24500
Guinea	1870	2490	8406	11862	11080
Jamaica	8651	12010	11571	12054	7300
Brazil	156	500	802	5538	7000
USSR	4700	4300	6470	6180	6180
Yugoslavia	1574	2099	2306	3138	3500
Hungary	1477	2022	2690	2950	2917
Greece	1270	2292	3006	3286	2900
India	707	1370	1273	1785	1923
Guyana	2919	4417	3250	1844	1791
Suriname	4360	6022	4928	4646	1750
France	2662	2992	2563	1921	1716
United States	1680	2115	1801	1559	679
World Total	**37460**	**57786**	**76895**	**90795**	**77596**
Major Producers as Percent of World Total	**89**	**90**	**91**	**92**	**94**
CHROMITE					
USSR	1270	1750	2080	2450	2450
South Africa	942	1427	2075	3414	2232
Albania	311	466	779	760	900
Brazil	32	27	702	833	670
Zimbabwe	586	360	590	554	431
Turkey	567	540	720	391	400
India	60	273	500	320	360
Finland	X	51	332	362	340
Philippines	554	566	520	496	330
New Caledonia	X	X	2	2	91
Iran	129	200	210	80	50
Madagascar	2	105	194	180	42
Greece	51	27	73	43	40
Yugoslavia	80	41	2	X	X
World Total	**4810**	**6053**	**6296**	**9467**	**8085**
Major Producers as Percent of World Total	**95**	**96**	**97**	**96**	**95**
COPPER					
Chile	606	711	828	1068	1190
United States	1226	1560	1282	1181	1038
USSR	700	570	765	900	1000
Canada	461	610	734	716	625
Zambia	696	684	677	596	543
Zaire	289	387	495	540	535
Poland	15	72	230	346	380
Peru	180	220	193	367	336
Philippines	63	160	226	305	309
Australia	92	158	219	244	256
South Africa	60	149	179	201	211
China	90	100	100	200	200
Japan	107	120	85	53	46
World Total	**5044**	**6036**	**7009**	**7739**	**8027**
Major Producers as Percent of World Total	**91**	**91**	**86**	**87**	**83**
IRON					
USSR	153432	195492	232803	244713	245000
Brazil	20754	40200	89894	114732	89000
Australia	6803	51189	97651	95534	71500
China	39000	40400	65000	68000	71000
India	23830	31366	41405	41936	38800
United States	88842	91201	80132	70730	38600
Canada	36250	47459	46868	48754	33495
South Africa	5816	7728	12298	26312	16605
France	59532	56805	49647	28981	15967
Liberia	15959	23661	24000	18187	14937
Sweden	29354	31509	30867	27184	13212
Venezuela	17510	22100	24772	16102	9715
World Total	**620982**	**769163**	**902018**	**895867**	**739133**
Major Producers as Percent of World Total	**80**	**83**	**88**	**89**	**89**
LEAD					
Australia	368	457	408	397	477
United States	273	519	564	550	449
USSR	350	440	480	420	435
Canada	275	353	349	297	252
Peru	154	157	184	189	206
China	100	100	100	160	160
Mexico	167	177	179	147	150
Yugoslavia	106	127	127	121	120
Morocco	77	73	64	115	102
Bulgaria	100	96	114	116	96
Korea, Dem People's Rep	60	70	120	125	95
Sweden	69	78	70	72	65
Namibia	88	73	53	50	38
World Total	**2695**	**3394**	**3434**	**3448**	**3324**
Major Producers as Percent of World Total	**81**	**80**	**82**	**80**	**80**
MANGANESE					
USSR	7576	6841	8459	9750	10400
South Africa	1567	2679	5769	5695	2886
Brazil	1396	1879	2156	2282	2100
Gabon	1280	1453	2245	2147	1857
China	1000	1000	1000	1600	1600
Australia	102	751	1555	1999	1353
India	1647	1651	1576	1692	1320
Mexico	131	274	428	447	350
Ghana	604	405	409	250	190
Hungary	213	169	182	83	85
Japan	303	270	158	80	77
Morocco	340	112	131	131	74
Zaire	378	347	309	6	X
World Total	**17743**	**18222**	**24656**	**26396**	**22443**
Major Producers as Percent of World Total	**93**	**98**	**99**	**99**	**99**
NICKEL					
USSR	85	110	152	154	170
Canada	242	277	242	185	122
Australia	0	30	76	74	90
New Caledonia	31	105	133	87	63
Indonesia	4	16	15	53	47
Cuba	X	35	37	37	37
South Africa	3	12	21	26	21
Dominican Rep	0	X	27	16	20
Philippines	0	0	9	48	19
Botswana	0	X	6	15	18
Greece	0	10	28	15	16
Brazil	1	3	3	4	11
Zimbabwe	0	11	10	15	10
Finland	3	5	5	7	5
United States	12	14	15	13	X
World Total	**426**	**628**	**808**	**780**	**689**
Major Producers as Percent of World Total	**90**	**100**	**96**	**96**	**94**
TIN					
Malaysia	64	73	64	61	42
USSR	23	27	30	36	37
Indonesia	15	19	25	33	27
Bolivia	23	29	24	22	24
Thailand	19	21	16	34	20
China	25	20	22	15	15
Brazil	2	4	5	7	12
Australia	4	9	10	12	10
United Kingdom	1	2	3	3	4
Zaire	6	6	5	3	3
Nigeria	10	8	5	3	2
World Total	**204**	**232**	**222**	**247**	**212**
Major Producers as Percent of World Total	**95**	**94**	**94**	**92**	**93**
ZINC					
Canada	826	1239	1229	1059	1070
USSR	470	610	690	785	805
Australia	355	487	501	495	695
Peru	254	299	385	488	553
United States	554	485	426	317	275
Mexico	225	266	289	236	257
Japan	221	280	254	238	256
Sweden	79	93	111	167	203
Ireland	1	97	67	229	186
Spain	39	98	84	183	175
Poland	152	187	210	188	146
Korea, Dem People's Rep	105	130	160	140	140
Germany, Fed Rep	108	129	116	121	114
Zaire	119	105	80	67	75
Italy	116	111	76	58	43
World Total	**4308**	**5464**	**5852**	**5962**	**6246**
Major Producers as Percent of World Total	**84**	**84**	**80**	**80**	**80**

(continued on next page.)

Table 8.4 CONTINUED

	Annual Production (thousand metric tons)				
	1965	1970	1975	1980	1983
PHOSPHATE ROCK					
United States	26746	35143	44276	54415	42573
USSR	13600	20800	24150	25300	27000
Morocco	9824	11400	13548	18824	20106
China	900	1700	3400	10726	12500
Tunisia	3040	3016	3481	4582	5924
Jordan	828	841	1353	3911	4749
Brazil	279	173	406	2612	3208
Israel	388	1162	882	2307	2969
South Africa	610	1685	1646	3185	2742
Togo	969	1508	1161	2933	2081
Nauru	1496	2114	2050	2087	1684
Senegal	1002	1128	1883	1632	1249
Christmas Island	857	1089	1391	1713	1094
Vietnam	1050	455	1400	90	220
Western Sahara	0	0	2682	X	X
World Total	**63776**	**87126**	**107678**	**139214**	**135000**
Major Producers as Percent of World Total	**97**	**94**	**96**	**96**	**95**
POTASH					
USSR	2368	4087	7944	8064	9300
Canada	1353	3103	5436	7532	6203
German Dem Rep	1926	2419	3019	3422	3430
Germany, Fed Rep	2384	2645	2223	2737	2100
France	1888	1904	1920	1894	1900
United States	2848	2476	2269	2239	1429
Israel	293	554	696	797	1000
Spain	405	521	567	658	657
United Kingdom	0	0	0	321	302
Jordan	0	0	0	X	170
Italy	318	365	282	156	140
Chile	X	X	X	25	22
China	X	X	300	12	20
World Total	**13724**	**18155**	**24740**	**27857**	**26678**
Major Producers as Percent of World Total	**100**	**100**	**100**	**100**	**100**
SULFUR					
USSR	1430	1600	7980	9590	9590
United States	7449	8676	11439	11866	9290
Canada	1876	4439	7536	7260	6625
Poland	431	2683	5081	5535	5240
Japan	250	342	2489	2784	2645
China	250	250	1070	2200	2600
France	1521	1735	1993	2216	2063
Mexico	1586	1381	2216	2217	1633
Germany, Fed Rep	77	176	1282	1799	1540
Spain	43	6	1371	1236	1131
Italy	16	143	703	604	458
German Dem Rep	125	109	365	360	360
Iran	32	414	495	220	65
World Total	**15531**	**22518**	**50190**	**54920**	**50472**
Major Producers as Percent of World Total	**97**	**97**	**88**	**87**	**86**

	Annual Production (thousand metric tons)				
	1965	1970	1975	1980	1983
ALUMINUM					
United States	2499	3607	3519	4654	3353
USSR	840	1100	1530	1760	2000
Canada	753	972	887	1068	1091
Germany, Fed Rep	234	309	678	731	730
Norway	279	522	595	653	715
Australia	88	206	214	303	475
China	100	130	200	360	380
France	341	381	383	432	361
Spain	52	120	210	386	358
Venezuela	X	23	50	328	343
Japan	294	733	1013	1091	256
United Kingdom	36	40	308	374	250
Netherlands	X	75	261	259	235
India	69	161	160	185	205
Italy	123	147	190	271	196
World Total	**6318**	**9653**	**12140**	**15371**	**13865**
Major Producers as Percent of World Total	**90**	**88**	**84**	**84**	**79**
CRUDE STEEL					
USSR	X	115886	141325	147941	153000
Japan	X	93322	102313	111395	97164
United States	X	119305	105816	101455	76761
China	X	18000	25000	37120	39952
Germany, Fed Rep	X	45041	40415	43838	35730
Italy	X	17277	21836	26501	21674
France	X	23773	21530	23176	17612
Czechoslovakia	X	11480	14323	15225	15024
United Kingdom	X	28316	20198	11278	14993
Brazil	X	5390	8308	15339	14659
Poland	X	11795	15007	19485	13600
Canada	X	11200	13025	15887	12828
Belgium	X	12607	11587	12325	10155
World Total	**X**	**594418**	**643798**	**713788**	**657224**
Major Producers as Percent of World Total	**X**	**86**	**84**	**81**	**80**

Source: U.S. Bureau of Mines.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 8.5 MAJOR CONSUMERS OF REFINED METALS, 1965–83

	Consumption of Refined Metals (thousand metric tons per year)					Metric Tons of Metal Consumed per Million Constant (1975) $US of GNP				
	1965	**1970**	**1975**	**1980**	**1983**	**1965**	**1970**	**1975**	**1980**	**1983**
ALUMINUM										
United States	2852	3488	3265	4454	4219	2.41	2.54	2.10	2.40	2.21
Japan	286	930	1171	1639	1801	1.85	2.35	2.35	2.56	2.54
Germany, Fed Rep	387	670	704	1042	1085	1.99	1.76	1.67	2.08	2.16
France	249	413	399	601	613	1.48	1.48	1.18	1.50	1.49
Italy	128	279	270	458	430	1.20	1.63	1.41	1.98	1.88
United Kingdom	364	404	393	409	323	2.12	1.93	1.70	1.63	1.23
Canada	169	223	293	312	295	1.95	1.76	1.82	1.68	1.57
Belgium	117	175	178	233	272	4.05	3.31	2.81	3.22	3.79
Spain	64	129	217	263	217	1.62	1.62	2.07	2.29	1.83
9 OECD Countries	4615	6712	6890	9411	9256	2.16	2.19	1.93	2.21	2.10
USSR	1000	1281	1580	1850	1850	X	X	X	X	X
China	95	180	300	550	620	X	1.52	1.94	2.65	2.41
Brazil	52	84	209	296	271	1.32	1.12	1.71	1.77	1.73
German Dem Rep	140	150	200	230	230	X	X	X	X	X
World Total	**6699**	**9928**	**11299**	**15285**	**15388**					
Major Consumers as Percent of World Total	**88**	**85**	**81**	**81**	**79**					
COPPER										
United States	1819	1854	1397	1868	1775	1.54	1.35	0.90	1.01	0.93
Japan	428	821	827	1158	1216	2.77	2.07	1.66	1.81	1.72
Germany, Fed Rep	536	698	635	748	737	2.75	1.84	1.51	1.49	1.47
France	287	331	365	433	390	1.71	1.18	1.07	1.08	0.95
United Kingdom	650	554	451	409	358	3.80	2.64	1.95	1.63	1.37
Italy	192	274	299	388	325	1.79	1.60	1.56	1.68	1.42
Belgium	99	145	177	304	258	3.42	2.75	2.81	4.20	3.60
Canada	204	229	196	209	195	2.35	1.81	1.21	1.13	1.04
8 OECD Countries	4214	4905	4346	5517	5255	2.01	1.64	1.26	1.33	1.23
USSR	785	960	1220	1300	1360	X	X	X	X	X
China	120	200	315	386	428	X	1.69	2.03	1.86	1.66
World Total	**6115**	**7265**	**7472**	**9361**	**9113**					
Major Consumers as Percent of World Total	**84**	**83**	**79**	**77**	**77**					
LEAD										
United States	754	894	820	1094	1135	0.64	0.65	0.53	0.59	0.59
Japan	147	211	189	393	360	0.95	0.53	0.38	0.61	0.51
Germany, Fed Rep	271	309	225	333	318	1.39	0.81	0.53	0.66	0.63
United Kingdom	312	262	238	296	293	1.82	1.25	1.03	1.18	1.12
Italy	94	168	146	275	229	0.88	0.98	0.76	1.19	1.00
France	145	193	174	213	196	0.86	0.69	0.51	0.53	0.48
Yugoslavia	43	45	83	128	133	2.08	1.95	2.69	3.14	3.29
Spain	87	78	74	111	101	2.20	0.97	0.70	0.96	0.86
8 OECD Countries	1852	2158	1948	2842	2765	0.91	0.74	0.58	0.70	0.66
USSR	385	486	620	800	805	X	X	X	X	X
China	100	160	185	210	220	X	1.35	1.19	1.01	0.85
Bulgaria	X	77	95	110	117	X	X	X	X	X
German Dem Rep	80	100	91	100	98	X	X	X	X	X
Mexico	56	94	72	85	86	1.64	1.49	0.83	0.72	0.73
World Total	**3194**	**3871**	**3914**	**5348**	**5229**					
Major Consumers as Percent of World Total	**77**	**79**	**77**	**78**	**78**					
NICKEL										
United States	156	141	133	142	139	0.13	0.10	0.09	0.08	0.07
Japan	27	98	90	122	115	0.17	0.25	0.18	0.19	0.16
Germany, Fed Rep	31	41	43	68	63	0.16	0.11	0.10	0.13	0.13
France	21	36	32	38	33	0.12	0.13	0.09	0.10	0.08
Italy	9	20	17	27	23	0.09	0.12	0.09	0.12	0.10
United Kingdom	37	35	21	23	22	0.22	0.17	0.09	0.09	0.08
Sweden	13	23	22	20	16	0.35	0.36	0.30	0.26	0.21
Finland	0	0	1	9	10	0.02	0.01	0.02	0.29	0.29
Canada	8	11	11	10	5	0.09	0.08	0.07	0.05	0.03
Austria	3	6	4	5	4	0.21	0.18	0.11	0.12	0.09
10 OECD Countries	306	410	374	465	429	0.32	0.24	0.19	0.20	0.17
USSR	110	130	115	132	140	X	X	X	X	X
China	X	X	18	18	19	X	X	X	0.09	0.07
India	X	X	3	12	13	X	X	X	0.11	0.11
World Total	**428**	**567**	**570**	**715**	**683**					
Major Consumers as Percent of World Total	**97**	**95**	**90**	**88**	**88**					

(continued on next page.)

Table 8.5 CONTINUED

	Consumption of Refined Metals (thousand metric tons per year)					Metric Tons of Metal Consumed per Million Constant (1975) $US of GNP				
	1965	1970	1975	1980	1983	1965	1970	1975	1980	1983
TIN										
United States	63	57	56	56	46	0.05	0.04	0.04	0.03	0.02
Japan	18	29	28	31	30	0.12	0.07	0.06	0.05	0.04
Germany, Fed Rep	13	15	13	16	14	0.07	0.04	0.03	0.03	0.03
United Kingdom	21	19	14	10	10	0.12	0.09	0.06	0.04	0.04
France	10	11	10	10	8	0.06	0.04	0.03	0.03	0.02
Netherlands	4	6	4	5	5	0.09	0.07	0.04	0.05	0.05
Italy	6	7	8	6	4	0.05	0.04	0.04	0.03	0.02
Canada	5	5	4	5	4	0.06	0.04	0.03	0.03	0.02
Belgium	3	3	5	3	2	0.09	0.06	0.08	0.04	0.03
9 OECD Countries	142	150	142	141	123	0.07	0.05	0.04	0.03	0.03
USSR	29	17	23	25	29	X	X	X	X	X
China	15	13	14	13	13	X	0.11	0.09	0.06	0.05
Poland	3	4	4	3	5	X	X	X	X	X
Brazil	2	3	3	5	4	0.05	0.04	0.03	0.03	0.03
India	5	5	3	2	2	0.06	0.07	0.03	0.02	0.02
World Total	**227**	**228**	**231**	**235**	**215**					
Major Consumers as Percent of World Total	**86**	**84**	**82**	**81**	**82**					
ZINC										
Japan	322	623	547	752	771	2.08	1.57	1.10	1.18	1.09
United States	1221	1074	839	810	770	1.03	0.78	0.54	0.44	0.40
Germany, Fed Rep	334	396	297	406	406	1.71	1.04	0.71	0.61	0.81
France	186	220	223	330	271	1.10	0.79	0.65	0.82	0.66
Italy	116	178	150	236	208	1.08	1.04	0.73	1.02	0.91
United Kingdom	282	278	207	181	181	1.65	1.33	0.89	0.72	0.69
Belgium	123	128	103	155	166	4.26	2.42	1.63	2.14	2.31
Canada	85	110	150	133	144	0.98	0.87	0.93	0.72	0.77
8 OECD Countries	2669	3007	2516	3003	2916	1.27	1.01	0.73	0.73	0.68
USSR	401	510	900	1030	1050	X	X	X	X	X
China	100	150	220	200	300	X	1.26	1.42	0.96	1.17
Poland	114	129	152	178	143	X	X	X	X	X
World Total	**4068**	**4886**	**5028**	**6124**	**6154**					
Major Consumers as Percent of World Total	**81**	**78**	**75**	**72**	**72**					

Source: World Bureau of Metal Statistics (London)
0 = zero or one-half the unit of measure; X = not available
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 8.1 Production of Commercial Energy, 1970–83

Source: U.N. Statistical Office, *Energy Statistics Yearbook, 1982* and *1983*, (United Nations, New York, 1984 and 1985), Table 3.

Energy data are compiled by the U.N. Statistical Office primarily from responses to questionnaires sent to national governments, supplemented by official national statistical publications. Additional data and analysis are provided by OECD, OPEC, ILO, FAO, the International Atomic Energy Agency, the International Sugar Organization, and the U.S. Department of Energy. Where official data are not available, the U.N. Statistical Office prepares estimates based on professional or commercial literature.

All units are petajoules (PJ), which are 10^{15} (one quadrillion) joules. One petajoule equals .000948 Quads (quadrillion British Thermal Units) and is equivalent to 163,400 "U.N. standard" barrels of oil, or 34,140 "U.N. standard" metric tons of coal. The heat content of various fuels has been converted to coal-equivalent and then petajoule-equivalent values using country- and year-specific conversion factors. For example, a metric ton of hard coal produced in Argentina has an energy value of 0.843 metric tons of standard coal equivalent (7 million kcal) while a metric ton of hard coal produced in Turkey has an energy value of 0.929 metric tons of coal equivalent. The original national production data for hard coal were multiplied by these conversion factors, and the resulting figures in metric tons of coal-equivalent were multiplied by 29.3076×10^{-6} to yield petajoule equivalents. Similarly, other fuels were converted to coal equivalent and petajoule-equivalent terms.

Only commercially traded fuels of the following types are included in the production statistics:

1. Solid fuels include hard coal, lignite, peat, and oil shale burned directly;
2. Liquid fuels include crude petroleum and natural gas liquids;
3. Gaseous fuels include natural gas;
4. Primary electricity includes hydro, geothermal, and nuclear electric power generation expressed as the energy value of the electricity. It is given in gross terms, without deductions for plant use and transmission losses.

Fuelwood, bagasse, charcoal, and new forms of solar energy are excluded from the production figures even when traded commercially.

Table 8.2 Consumption of Commercial Energy and Total Requirements, 1970–83

Sources: Energy data: U.N. Statistical Office, *Energy Statistics Yearbook 1982* and *1983*, (United Nations, New York, 1984 and 1985), Table 3 and Table 4. Population data: U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections As Assessed in 1982* (United Nations, New York, 1985). Gross National Product data: unpublished World Bank data.

A gigajoule (GJ) is one billion (10^9) joules. A megajoule (MJ) is one million (10^6) joules.

Consumption of commercial energy equals domestic production plus net imports, minus net stock increases, minus aircraft and marine bunkers.

The imports referred to under "Imports as Percentage of Consumption" are net imports, minus stock increases, minus bunkers.

"Total Requirements" is an estimate of the total amount of energy a nation requires in a given year. It differs from total commercial energy consumption by the inclusion of traditional fuels (fuelwood, charcoal, bagasse, animal and vegetable wastes) and by the treatment of primary electricity.

To calculate total requirements, primary electricity is valued on a fossil-fuel avoided basis rather than an energy-output basis. For example, a hydroelectric power plant that produces 1000 kWh of electricity provides the equivalent heat of 0.123 metric tons of coal. However, more than 0.123 metric tons of coal would be required to produce 1000 kWh of electricity. Much of the energy released from coal combustion in a power plant is used in the mechanical work of turning dynamos or lost in waste heat, so less energy is embodied in the final electricity than in the initial coal. The efficiency of a thermal electric plant is the ratio between final electrical energy produced and initial potential energy supplied. Although this rating varies widely from country to country and from plant to plant, the U.N. Statistical Office uses a standard factor of 30 percent efficiency to estimate the fossil fuel value of hydro, geothermal, and nuclear electricity.

Fuelwood and charcoal consumption are estimated from population data and country-specific per-capita consumption figures. These per capita consumption estimates were prepared by the FAO after an assessment of the available consumption data. Specific consumption of non-coniferous fuelwood ranges from .0016 m^3 per capita per year in Jordan to .9783 m^3 per capita per year in Benin. Similar estimates were prepared for coniferous fuelwood and charcoal. Although the energy value of fuelwood and charcoal varies widely, the U.N. Statistical Office uses standard factors of .33 metric tons of coal equivalent per cubic meter of fuelwood and .986 metric tons of coal equivalent per metric ton of charcoal.

Bagasse production is based on sugar production data in the *Sugar Yearbook* of the International Sugar Organization. It is assumed that 3.26 metric tons of fuel bagasse at 50 percent moisture are produced per metric ton of extracted cane sugar. The energy of a metric ton of bagasse is valued at .264 metric tons of coal equivalent.

Table 8.3 Nuclear Power and Waste Generation, 1970–84

Sources: Reactor and capacity data for 1970 for all countries except USSR: *Nucleonics Week* (January 1971). Reactor and capacity data for 1984 for all countries: U.S. Department of Energy, *Commercial Nuclear Power: Prospects for the United States and the World* (U.S. Department of Energy/Energy Information Administration, Washington, D.C., September 1985). Nuclear electricity generation for 1973: unpublished U.S. Department of Energy data. Total electricity generation for 1973: OECD, *Energy Balances of OECD Countries 1970–82* (Organization for Economic Cooperation and Development/International Energy Agency, Paris, 1984) and OECD, *Energy Balances of Developing Countries 1971–82* (Organization for Economic Cooperation and Development/International Energy Agency, Paris, 1984). Nuclear electricity generation as percent of total for nonmarket countries for 1983: *Nuclear Engineering International*, Vol. 29, p. 3 (October 1984). Data for USSR reactors, capacity, and nuclear electricity generation as percent of total for 1970: W. P. Geddes, "Uranium and Nuclear Power in the Soviet Bloc," (unpublished monograph, November 1984). Spent fuel inventory data: U.S. Department of Energy, *World Nuclear Fuel Cycle Requirements* (U.S. Department of Energy/Energy Information Administration, Washington, D.C., November 1985).

A gigawatt of electricity (GWe) is one billion (10^9) watts of electric power.

All data are for December 31 of the year indicated.

Number of reactors refers to those power reactors that have produced electricity into the electrical grid, although not necessarily at full power. Reactors in extended shutdown are included. Reactors under construction or which have been decommissioned are excluded.

Installed capacity is on a net basis. Electric requirements of the generating plant, usually about 5 to 10 percent of gross generation, have been deducted.

Nuclear electricity generation as percent of total is the total electricity generated into grids by nuclear power plants divided by electricity generation from all sources.

Spent fuel inventories are expressed as cumulative totals to the years given and are net of reprocessing. "Heavy metal" refers to the actinide elements (uranium, plutonium, etc.) contained in the spent fuel.

Table 8.4 Production of Selected Materials, 1965–83

Source: U.S. Bureau of Mines, *Minerals Yearbook* (U.S. Government Printing Office, Washington, D.C., 1967, 1977, and 1983).

Production refers to the amount of material mined or refined in the given year.

Potash refers to marketable potash.

Sulfur refers to elemental sulfur.

Aluminum refers to primary aluminum.

Crude steel refers to steel ingots and castings.

Production figures for the ten ores refer to the metal content of mine output. However, common definitions are not always used, making inter-country and inter-year comparisons difficult. In 1983, for example, Brazil's manganese production was qualified as "manganese ore and concentrate, marketable, gross weight, direct sales and beneficiated", while Morocco's production figures were for "manganese ore, largely chemical grade". In 1965, South Africa's manganese production is reported for "manganese, ore and concentrate, gross weight, chemical and metallurgical". Gabon's manganese production data for 1965 are for "ore, 50–53 percent manganese", as well as "battery and chemical grade pellets, 82–84 percent manganese". Similar problems exist with the data for other materials; refer to the source for specific definitions and qualifications.

The countries listed represent the top ten producers of each material for the five years in the table. Since two or three countries may have moved into and out of the top ten grouping over the 18-year period, more than ten countries are listed for some materials. Countries are listed in descending order of 1983 production.

Some of the data for 1983 are estimates. See source for details.

Table 8.5 Major Consumers of Refined Metals, 1965–83

Sources: Metal consumption: *World Metal Statistics*, (World Bureau of Metal Statistics, London, April 1970, December 1974, February 1979, and June 1985). GNP for 1970–83: unpublished World Bank data. GNP for 1965: World Bank, *World Tables* (The Johns Hopkins University Press, Baltimore, Maryland, 1983).

The World Bureau of Metal Statistics publishes consumption data for the six metals presented as well as occasional consumption data for antimony and cadmium. These data are compiled from metal companies, government agencies, trade groups, and statistical bureaus. Obviously incorrect data are revised, but most data are compiled and reported without adjustment or restrospective revisions.

Consumption of refined metals is determined on the basis of first use after refinement. Metal that is melted and recycled is not counted as new consumption; scrap that is refined is treated as new consumption. The metal used in a product that is then exported is considered to be consumed by the producing country rather than by the importing country.

The countries listed represent the ten largest consumers of each metal for the five years in the table. Since two or three countries may have moved into and out of the top ten grouping over the 18-year period, more than ten countries are listed for some metals. Countries are listed within groupings in descending order of their 1983 consumption.

The world total refers to the aggregate consumption of all countries, not only those listed. Major consumers refers to the 10 to 15 countries listed. Major OECD consumers refers to the listed members of the Organization for Economic Cooperation and Development, including Yugoslavia.

Copper data for China for all years includes, in addition to the People's Republic, the centrally planned Asian countries of Viet Nam, Democratic People's Republic of Korea, Democratic Kampuchea, and Lao People's Democratic Republic. The consumption of these countries is assumed to be minor in comparison to that of China.

9. Freshwater

The demand for freshwater has increased with the rapid growth of population, agriculture, and industry, and as a result formerly abundant supplies of clean water have been depleted or polluted. The basic unit of concern in dealing with freshwater is the watershed or river basin, defined as the catchment area from which the waters of a river or river system flow. Human activities that modify the natural flow of water and sediments—building dams, cutting down forests, causing excessive soil erosion, discharging pollutants—have impacts throughout the watershed. In most large river basins (see Table 9.3) these impacts are imposed on people living in other regions or in other countries, and this can lead to serious conflicts.

Ideally, comparable and timely statistics on water resources, water quality, and floods should be available for river basins as well as for countries. But because of data limitations, the statistics in this chapter highlight conditions and trends for countries only.

A country's water resources can be compared with others in terms of per capita availability. (See Table 9.1.) A supply of 1,000 cubic meters or less per capita per annum is considered very low; 1,000–5,000 is low; 5,000–10,000 is medium; and 10,000 and above is high. Of the 98 countries for which data are available, 14 are rated very low; 36 are rated low; 14 are rated medium; and 34 are rated high.

Availability statistics include water from both internal and transit sources. For example, Hungary has an estimated 120 cubic kilometers of water potentially available for use: 6 from internal stable runoff and 114 from imports, mostly from the Danube. Clearly, however, not all this water is available for withdrawal because most of it flows to other countries downstream.

In water-rich countries, per-capita withdrawals are a small fraction of available supplies. A country may be reaching a critical level of exploitation if it uses (withdraws) one third or more of its available supplies in an average year. Nineteen of the 98 countries are in this situation. In arid and semi-arid countries such as Sudan, Yemen, Israel, Saudi Arabia, and Libya, available supplies are almost fully utilized.

Freshwater quality can be measured in terms of pollutant discharges, ambient concentrations, and impacts on human health and on natural systems. Table 9.2 presents information on ambient levels of pollution in major rivers as reported to the Organization for Economic Co-operation and Development (OECD).

One measure of water quality is the amount of dissolved oxygen (DO), which indicates the extent to which freshwater can support aquatic life. Depending on temperature, water with less than 5 milligrams of DO per liter is considered of poor quality. The data indicate that DO in many rivers in OECD countries has increased in the last decade because the amount of biodegradable waste discharged into streams has been reduced.

Water authorities try to maintain average phosphorous concentrations below 0.1 milligrams per liter of water, to limit excessive algal growth and the process of eutrophication. By this measure a few countries have improved, but most have not achieved the recommended level. Nitrates are found in increasing concentrations in many OECD countries' rivers because of increased fertilizer use and other causes.

Lead, cadmium, chromium, copper, and other metals have caused water quality problems in OECD countries. Most often these are hot spots where a small stretch of river is seriously polluted and the use of the water (or fish from the river) is curtailed or prohibited. Levels of cadmium above 5 micrograms per liter and lead above 50 micrograms per liter can make water supplies unsafe for human and animal consumption. However, almost all annual average data fall considerably below these guidelines.

Between 1964 and 1982, floods killed 80,000 people and affected 221 million more. Floods and cyclones are causing increasing damage and death tolls because more and more houses and businesses are being built on low-lying flood plains and in the path of tropical storms. (See Table 9.4.) Rapid population growth and an inequitable distribution of land in some countries force many more people to live in hazardous zones. Compounding the problem is excessive sediment from erosion upstream (caused largely by deforestation) that settles in river channels, leaving less capacity for storm runoff.

Table 9.1 FRESHWATER, AVAILABILITY AND USE, 1970s

		Availability		Withdrawal		Sectoral Use (percent)			
	Year of Information	Total (cubic kilometers per year)	Per Capita (thousand cubic meters per year)	Total (cubic kilometers per year)	Per Capita (thousand cubic meters per year)	Public	Industry (self-supplied)	Electricity Generation Facilities (cooling)	Agriculture (irrigation)
WORLD									
AFRICA									
Algeria	1970	25.00	1.82	2.00	0.15	13	6	0	81
Angola	X	X	X	X	X	X	X	X	X
Benin	1970	26.00	9.60	X	X	X	X	X	X
Botswana	X	X	X	X	X	X	X	X	X
Burkina Faso	X	X	X	X	X	X	X	X	X
Burundi	X	X	X	X	X	X	X	X	X
Cameroon	X	208.00	27.43	X	X	X	X	X	X
Cape Verde	X	X	X	X	X	X	X	X	X
Central African Rep	X	X	X	X	X	X	X	X	X
Chad	X	X	X	X	X	X	X	X	X
Comoros	X	X	X	X	X	X	X	X	X
Congo	X	X	X	X	X	X	X	X	X
Djibouti	1973	X	X	0.01	0.03	X	X	X	X
Egypt	1976	56.00	1.47	45.00	1.18	1	0	0	98
Equatorial Guinea	X	X	X	X	X	X	X	X	X
Ethiopia	X	110.00	3.79	X	X	X	X	X	X
Gabon	X	X	X	X	X	X	X	X	X
Gambia	X	X	X	X	X	X	X	X	X
Ghana	1970	53.00	6.15	0.30	0.03	44	3	0	54
Guinea	X	X	X	X	X	X	X	X	X
Guinea-Bissau	X	X	X	X	X	X	X	X	X
Ivory Coast	X	74.00	10.94	X	X	X	X	X	X
Kenya	X	14.80	1.08	X	X	X	X	X	X
Lesotho	X	X	X	X	X	X	X	X	X
Liberia	X	X	X	X	X	X	X	X	X
Libya	1977-78	0.70	0.26	1.47	0.55	17	0	0	83
Madagascar	X	40.00	5.26	X	X	X	X	X	X
Malawi	X	X	X	X	X	X	X	X	X
Mali	X	X	X	X	X	X	X	X	X
Mauritania	1978	X	X	0.73	0.47	2	0	0	98
Mauritius	1974	2.20	2.53	0.36	0.41	X	X	X	X
Morocco	1972	25.00	1.63	8.00	0.52	4	3	0	94
Mozambique	X	X	X	X	X	X	X	X	X
Niger	X	X	X	X	X	X	X	X	X
Nigeria	X	X	X	X	X	X	X	X	X
Rwanda	X	X	X	X	X	X	X	X	X
Senegal	X	X	X	X	X	X	X	X	X
Sierra Leone	X	X	X	X	X	X	X	X	X
Somalia	X	X	X	X	X	X	X	X	X
South Africa	1970	50.00	2.20	9.20	0.40	17	0	0	83
Sudan	1970	18.50	1.33	18.15	1.31	2	0	0	98
Swaziland	X	X	X	X	X	X	X	X	X
Tanzania, United Rep	1970	X	X	0.48	0.04	38	0	0	63
Togo	X	11.50	5.11	0.05	0.02	90	0	0	10
Tunisia	1977	3.35	0.57	1.07	0.18	19	5	0	77
Uganda	1970	X	X	0.20	0.02	43	0	0	57
Zaire	X	X	X	X	X	X	X	X	X
Zambia	1970	X	X	0.36	0.09	72	0	0	28
Zimbabwe	X	X	X	X	X	X	X	X	X
NORTH AMERICA									
Barbados	1962	0.05	0.23	0.03	0.12	45	35	0	20
Canada	1977	3122.00	134.24	30.00	1.29	13	39	39	10
Costa Rica	1970	95.00	54.85	1.35	0.78	0	8	0	92
Cuba	1975	34.50	3.70	8.10	0.87	14	4	0	83
Dominican Rep	1975	20.00	4.04	X	X	X	X	X	X
El Salvador	1975	18.95	4.57	1.00	0.24	17	0	0	83
Guatemala	1970	116.00	21.67	0.73	0.14	0	18	0	82
Haiti	X	11.00	2.13	X	X	X	X	X	X
Honduras	1970	102.00	38.65	1.34	0.51	0	4	0	96
Jamaica	1975	8.30	4.06	0.32	0.16	3	6	0	91
Mexico	1975	357.40	5.94	54.20	0.90	5	7	0	88
Nicaragua	1975	175.00	72.67	0.89	0.37	18	45	0	37
Panama	1975	144.00	82.38	1.30	0.74	12	11	0	77
Trinidad and Tobago	1975	X	X	0.15	0.14	0	50	0	50
United States	1975	2478.00	11.47	472.00	2.19	10	11	38	41
SOUTH AMERICA									
Argentina	1976	694.00	26.64	27.60	1.06	9	8	10	73
Bolivia	1959	X	X	X	X	1	1	0	97
Brazil	X	5190.00	48.04	X	X	X	X	X	X
Chile	1975	X	X	16.80	1.65	5	4	0	92
Colombia	1960	1070.00	68.86	X	X	14	0	0	86
Ecuador	1973	314.00	45.57	X	X	X	X	X	X
Guyana	1971	X	X	5.40	7.62	1	0	0	99
Paraguay	X	X	X	X	X	X	X	X	X
Peru	1975	40.00	2.64	X	X	7	0	0	93
Suriname	X	X	X	X	X	X	X	X	X
Uruguay	1965	X	X	0.65	0.24	15	8	0	77
Venezuela	1970	856.00	78.09	4.10	0.37	37	4	0	59

Table 9.1

	Year of Information	Availability		Withdrawal		Sectoral Use (percent)			
		Total (cubic kilometers per year)	Per Capita (thousand cubic meters per year)	Total (cubic kilometers per year)	Per Capita (thousand cubic meters per year)	Public	Industry (self-supplied)	Electricity Generation Facilities (cooling)	Agriculture (irrigation)
ASIA									
Afghanistan	1970	50.00	4.01	X	X	X	X	X	X
Bahrain	1975	0.00	0.00	0.20	0.74	10	6	0	84
Bangladesh	X	1357.00	17.72	X	X	X	X	X	X
Bhutan	X	X	X	X	X	X	X	X	X
Burma	1970	1082.00	39.57	X	X	X	X	X	X
China	1970	2680.00	3.23	X	X	X	X	X	X
Cyprus	1972	1.00	1.63	0.55	0.89	5	2	0	93
India	1975	1850.00	2.99	380.00	0.61	3	1	3	93
Indonesia	1978	2530.00	17.45	X	X	95	5	0	0
Iran	1975	117.50	3.52	45.40	1.36	3	0	0	97
Iraq	1969	84.50	9.03	42.30	4.52	1	5	0	93
Israel	1975	1.65	0.48	1.72	0.50	17	6	0	77
Japan	1975	547.00	4.90	117.90	1.06	17	33	0	50
Jordan	1975	0.85	0.33	0.38	0.15	1	2	0	97
Kampuchea, Dem	1970	88.10	12.70	X	X	X	X	X	X
Korea, Dem People's Rep	X	X	X	X	X	X	X	X	X
Korea, Rep	1976	63.00	1.23	10.70	0.21	11	13	0	75
Kuwait	1974	0.00	0.00	0.13	0.13	35	4	0	61
Lao People's Dem Rep	X	270.00	78.76	X	X	X	X	X	X
Lebanon	1975	4.30	1.55	0.75	0.27	13	0	0	87
Malaysia	1975	456.00	37.05	9.42	0.77	X	X	X	X
Mongolia	X	24.60	17.04	X	X	X	X	X	X
Nepal	1970	170.00	14.80	X	X	X	X	X	X
Oman	1975	0.66	0.86	0.43	0.56	2	0	0	98
Pakistan	1975	298.00	3.96	153.40	2.04	X	X	X	X
Philippines	1975	323.00	7.59	29.50	0.69	X	X	X	X
Qatar	1975	0.02	0.13	0.04	0.23	33	0	0	67
Saudi Arabia	1975	2.20	0.30	2.33	0.32	36	6	0	58
Singapore	1975	0.60	0.27	0.19	0.08	X	X	X	X
Sri Lanka	1970	43.20	3.45	6.30	0.50	0	2	0	98
Syrian Arab Rep	1976	35.30	4.75	7.00	0.94	6	0	0	94
Thailand	1975	110.00	2.66	X	X	1	0	0	99
Turkey	1970	167.00	4.73	11.80	0.33	7	2	7	85
United Arab Emirates	1975	0.22	0.43	0.36	0.71	9	0	0	91
Viet Nam	X	X	X	X	X	X	X	X	X
Yemen	X	X	X	X	X	X	X	X	X
Yemen, Dem	1975	1.50	0.91	1.93	1.17	1	0	0	99
EUROPE									
Albania	1967	27.50	14.71	0.20	0.11	1	1	98	0
Austria	1975	90.00	11.97	2.75	0.37	31	69	0	0
Belgium	1971	12.50	1.30	8.26	0.86	6	37	47	10
Bulgaria	1971	197.00	23.14	X	X	33	67	0	0
Czechoslovakia	1975	90.00	6.08	5.02	0.34	24	72	0	5
Denmark	1970	12.90	2.62	0.77	0.16	43	38	1	18
Finland	1972	104.00	22.58	4.61	1.00	7	85	0	8
France	1975	180.00	3.42	27.00	0.51	16	20	44	19
German Dem Rep	1975	26.20	1.55	8.30	0.49	10	77	0	13
Germany, Fed Rep	1975	160.00	2.59	33.20	0.54	10	35	55	0
Greece	1975	55.00	6.08	4.28	0.47	14	2	1	84
Hungary	1972	120.00	11.59	5.60	0.54	9	34	9	48
Ireland	1972	43.70	14.79	1.68	0.57	11	14	69	6
Italy	1970	167.00	3.12	36.00	0.67	19	4	5	71
Luxembourg	1973	3.36	9.28	0.06	0.17	47	50	0	3
Malta	1977	0.03	0.07	0.02	0.06	X	X	X	X
Netherlands	1972	90.50	6.94	14.41	1.11	5	24	40	32
Norway	1972	383.00	98.79	1.40	0.36	14	84	0	2
Poland	1976	58.80	1.73	15.90	0.47	14	21	40	25
Portugal	1977	87.50	9.11	6.46	0.67	7	38	0	55
Romania	1971	192.00	9.43	X	X	15	85	0	0
Spain	1975	110.00	3.09	25.00	0.70	7	5	17	72
Sweden	1975	183.00	22.34	5.00	0.61	50	50	0	0
Switzerland	1973	50.00	7.81	2.50	0.39	44	48	0	8
United Kingdom	1972	162.70	2.93	17.66	0.32	23	41	35	1
Yugoslavia	1976	244.00	11.43	8.88	0.42	16	38	39	7
USSR	1975	4714.00	18.60	226.00	0.89	8	15	14	63
OCEANIA									
Australia	1975	343.00	25.17	16.90	1.24	X	X	X	X
Fiji	X	X	X	X	X	X	X	X	X
New Zealand	1967-68	397.00	140.78	1.01	0.36	52	11	23	14
Papua New Guinea	X	X	X	X	X	X	X	X	X
Solomon Islands	X	X	X	X	X	X	X	X	X
ANTARCTICA									

Source: Bureau of Geological and Mining Research, National Geological Survey, France.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

Table 9.2 WATER QUALITY, SELECTED RIVERS, 1970–83

	Dissolved Oxygen (DO) (milligrams per liter)					Biological Oxygen Demand (BOD) (milligrams per liter)					Nitrates (milligrams per liter)					Phosphorus (milligrams per liter)				
	1970	1975	1980	1983	Latest Three Years of Data (average)	1970	1975	1980	1983	Latest Three Years of Data (average)	1970	1975	1980	1983	Latest Three Years of Data (average)	1970	1975	1980	1983	Latest Three Years of Data (average)
Canada																				
St. Lawrence	8.1	10.0	X	X	X	X	X	X	X	X	0.19	0.23	0.16	0.29	0.19	0.05	0.03	0.07	0.06	0.07
Mackenzie	X	X	X	X	X	X	X	X	X	X	0.08	0.11	0.11	0.08	0.10	X	0.02	0.01	0.01	0.01
Fraser	X	X	X	X	X	X	X	X	X	X	0.05	0.30	0.06	0.12	0.08	0.00	0.11	X	X	X
Nelson	X	X	X	X	X	X	X	X	X	X	0.04	0.40	0.06	0.09	0.06	X	0.02	0.01	0.02	0.01
United States																				
Delaware-Trenton	9.6	10.8	11.9	10.3	11.1	1.9	2.0	2.2	2.6	2.8	[a] X	0.88	1.08	X	0.97	[a] X	0.10	0.10	0.09	0.09
Mississippi-St. Franc	8.4	8.5	8.3	8.9	8.9	2.4	2.2	1.7	1.1	1.8	[a] X	0.98	1.20	1.58	1.64	[a] X	0.19	0.23	0.17	0.23
Japan																				
Ishikari	8.7	10.7	10.6	10.6	10.5	1.7	1.4	1.4	1.5	1.4	0.36	X	0.53	X	X	X	0.09	0.09	0.07	0.09
Yodo	8.3	8.9	9.0	8.2	8.0	3.6	3.2	3.8	4.2	4.1	X	0.80	0.76	X	0.66	X	0.19	0.22	0.16	0.18
Australia																				
Brisbane Estuary	X	5.6	6.4	6.0	6.2	X	1.6	1.0	1.2	1.2	X	0.34	0.85	1.05	0.93	X	0.20	0.38	0.48	0.43
New Zealand																				
Waikato	X	9.0	X	X	X	X	1.5	X	X	X	X	0.20	X	X	X	X	0.60	X	X	X
Belgium																				
Meuse-Heer	8.2	10.8	10.6	X	10.7	4.4	5.6	4.2	X	4.7	1.80	7.80	2.18	X	2.09	X	1.23	0.22	X	0.17
Meuse-Lanaye	7.7	8.9	9.5	X	9.2	12.5	4.7	3.9	X	4.0	3.90	9.40	2.52	X	2.50	X	1.41	0.55	X	0.55
Escaut-Bleharies	X	4.0	5.9	X	4.7	X	24.1	10.7	X	9.6	X	0.77	4.17	X	3.58	X	0.70	0.94	X	1.03
Escaut-Doel	6.2	1.3	1.9	X	2.1	4.0	8.2	5.0	X	14.0	3.00	7.35	4.17	X	3.18	X	1.06	0.55	X	0.63
Denmark																				
Gudenaa	X	X	9.7	10.7	10.2	X	X	3.4	4.5	4.3	X	1.25	1.70	2.00	1.84	X	0.30	0.16	0.18	0.13
Skjernaa	X	X	10.5	10.4	10.4	X	X	7.3	8.0	8.3	X	X	3.00	3.18	2.92	X	X	0.22	0.13	0.17
Susaa	X	X	X	8.7	9.1	X	X	X	2.0	2.1	X	5.27	6.73	5.21	6.09	X	0.66	0.26	0.34	0.30
Finland																				
Tornionjoki	11.9	11.9	12.0	X	11.9	1.6	1.6	X	X	1.7	X	X	X	X	X	0.02	0.02	0.02	X	0.03
Kymijoki	9.5	10.8	9.9	X	10.8	3.5	2.4	X	X	2.5	X	X	X	X	X	0.05	0.03	0.03	X	0.03
France																				
Loire-Nantes	10.7	11.1	11.8	12.0	11.6	6.7	4.4	6.6	6.7	6.0	1.58	1.45	1.99	1.85	2.12	X	X	X	X	X
Seine-Tancerville	X	3.3	4.9	5.9	5.2	X	10.2	6.6	4.1	4.9	X	4.18	5.35	5.24	5.18	X	X	X	X	X
Garonne-Bordeaux	9.7	9.9	10.1	9.9	9.9	2.2	1.5	2.3	2.3	2.1	1.15	0.93	1.83	1.67	1.73	X	X	X	X	X
Rhine-Selz	8.2	9.2	10.9	8.6	8.9	X	4.1	4.8	3.0	3.6	X	1.58	2.92	2.94	2.62	X	X	0.47	0.20	0.23
Germany, Fed Rep																				
Rhine-Bimmen	5.6	6.5	8.4	9.1	9.0	6.1	6.9	3.6	3.5	3.6	1.82	3.12	3.80	3.88	3.67	0.52	0.75	0.48	0.59	0.51
Italy																				
Po	X	X	X	X	X	X	7.3	7.3	X	7.2	X	1.35	1.35	X	X	X	0.23	0.23	X	X
Netherlands																				
Meuse-Keizersveer	8.6	9.4	10.0	9.7	9.8	6.2	4.2	2.3	2.0	2.3	3.07	3.69	3.72	3.70	3.62	0.41	0.57	0.50	0.42	0.42
Meuse-Eijsden	9.8	9.5	9.8	8.7	9.1	4.1	3.7	2.8	2.8	2.8	2.45	2.51	2.78	2.71	2.68	0.43	0.73	0.58	0.53	0.50
Scheur-Maasluis	X	7.1	8.1	8.7	8.5	X	3.3	2.2	1.5	1.9	X	3.37	3.84	3.80	3.71	X	0.56	0.65	0.56	0.53
Ijssel-Kampen	6.7	6.7	8.1	8.2	8.4	5.7	6.3	3.9	2.3	2.7	2.76	3.46	4.27	4.33	4.13	0.43	0.62	0.63	0.57	0.57
Norway																				
Skienselva	X	X	X	6.0	X	X	2.5	3.5	X	X	X	0.35	0.35	0.34	0.34	X	0.01	0.01	0.01	0.01
Portugal																				
Tejo	9.0	X	9.0	X	X	1.6	X	2.5	X	X	0.52	X	5.60	X	X	X	X	2.00	X	X
Spain																				
Guadalaviar	X	X	X	X	X	X	12.3	11.8	X	8.2	X	7.54	9.60	X	8.05	X	0.83	0.86	X	0.43
Sweden																				
Dalalven	X	X	X	X	X	X	X	X	X	X	0.12	0.11	0.14	0.12	0.12	0.02	0.02	0.02	0.02	0.02
Switzerland																				
Rhine-Village	11.6	11.2	10.3	10.2	10.4	X	X	X	X	X	X	X	1.39	1.43	1.39	X	0.07	0.17	0.13	0.16
Aare-Brugg	X	10.2	10.2	X	10.4	X	X	X	X	X	X	1.32	1.43	1.38	1.33	X	0.23	0.11	0.09	0.44
Limmat-Baden	X	X	9.1	X	X	X	X	X	X	X	X	X	0.91	0.97	0.92	X	X	0.13	0.10	0.12
Rhone-Port du Sceaux	X	10.7	10.9	X	11.0	X	X	X	X	X	X	0.49	0.52	0.51	0.46	X	0.12	0.10	0.10	0.10
United Kingdom																				
Thames	X	10.8	9.9	9.8	9.9	X	4.2	X	X	4.0	X	6.50	6.89	7.10	6.99	[b] X	1.07	1.16	X	1.11
Severn	X	10.5	10.3	11.5	10.7	X	3.9	X	X	3.2	X	5.52	5.80	5.45	5.64	[b] X	0.75	0.54	X	0.58
Clyde	X	7.7	9.4	8.4	8.5	X	7.3	5.6	X	5.3	X	2.66	1.85	2.15	1.94	[b] X	0.69	0.50	X	0.48
Mersey	X	5.1	6.1	6.1	6.1	X	8.6	X	X	X	X	1.84	2.29	2.19	2.19	X	X	X	X	X
Yugoslavia																				
Dunav	9.6	9.1	9.2	X	9.5	3.4	2.5	3.5	X	3.7	X	1.70	5.80	X	2.50	X	X	X	X	X
Drava	8.8	7.4	10.1	X	10.0	3.4	2.6	3.1	X	3.1	4.60	5.20	7.70	X	6.73	X	X	X	X	X

Table 9.2

	Lead (micrograms per liter)					Cadmium (micrograms per liter)					Chromium (micrograms per liter)					Copper (micrograms per liter)				
	1970	1975	1980	1983	Latest Three Years of Data (average)	1970	1975	1980	1983	Latest Three Years of Data (average)	1970	1975	1980	1983	Latest Three Years of Data (average)	1970	1975	1980	1983	Latest Three Years of Data (average)
Canada																				
St. Lawrence	X	X	1.00	3.00	1.33	X	X	1.00	1.00	1.00	0.00	0.00	X	X	X	0.01	0.01	14.00	17.00	13.67
Mackenzie	10.00	5.00	4.00	3.00	3.67	X	1.00	1.00	1.00	1.00	c X	0.01	X	X	X	10.00	7.00	2.00	14.00	9.33
Fraser	10.00	2.00	X	X	X	X	X	X	X	X	X	X	X	X	X	10.00	4.00	X	X	X
Nelson	X	4.00	4.00	7.00	5.00	X	1.00	1.00	1.00	1.00	X	X	X	X	X	X	4.00	5.00	16.00	7.67
United States																				
Delaware-Trenton	X	6.00	2.00	X	2.00	X	2.00	3.50	X	2.75	d X	27.50	10.00	X	10.00	d X	20.00	3.50	X	3.50
Mississippi-St. Franc	X	2.00	2.00	X	2.33	X	2.00	2.00	X	2.00	d X	7.80	10.00	X	9.77	d X	4.00	6.30	X	6.10
Japan																				
Ishikari	210.00	1.00	5.00	X	8.00	X	X	X	X	X	X	X	X	X	X	35.00	3.00	18.00	3.00	3.67
Yodo	X	1.00	0.00	X	0.00	X	X	X	X	X	d X	X	X	X	X	d X	0.00	8.00	X	6.67
Australia																				
Brisbane Estuary	c X	5.70	5.30	5.00	5.10	c X	2.30	2.00	2.00	2.00	X	X	X	20.00	X	X	9.70	5.60	5.00	5.20
New Zealand																				
Waikato	X	10.00	X	X	X	X	1.00	X	X	X	X	10.00	X	X	X	X	1.00	X	X	X
Belgium																				
Meuse-Heer	X	1.40	4.00	X	5.33	X	0.80	0.30	X	0.83	X	1.20	1.20	X	2.80	X	4.70	7.00	X	7.50
Meuse-Lanaye	X	5.70	20.00	X	12.00	X	2.60	1.20	X	1.73	X	4.60	2.70	X	3.40	X	4.50	11.30	X	12.23
Escaut-Bleharies	X	11.00	18.00	X	15.67	X	1.60	2.60	X	3.17	X	12.60	9.80	X	12.73	X	6.80	15.60	X	16.67
Escaut-Doel	X	203.50	25.00	X	38.00	X	1.50	5.80	X	5.73	X	15.60	25.10	X	24.37	X	15.50	24.40	X	27.60
Denmark																				
Gudenaa	X	X	X	X	X	X	X	10.00	1.00	4.00	X	X	X	X	X	X	X	X	X	X
Skjernaa	X	X	X	X	X	X	X	X	10.00	X	X	X	X	X	X	X	X	X	X	X
Susaa	X	X	X	X	X	X	X	X	1.00	X	X	X	X	X	X	X	X	X	X	X
Finland																				
Tornionjoki	c X	X	0.06	0.27	0.78	c X	X	0.01	0.02	0.04	c X	1.00	3.00	0.52	2.17	X	2.00	2.80	1.70	1.83
Kymijoki	c X	X	0.28	0.37	0.55	c X	X	0.01	0.02	0.04	X	X	X	0.67	2.22	X	X	1.40	1.50	1.63
France																				
Loire-Nantes	e X	10.00	4.00	5.00	4.67	f X	10.00	1.00	2.00	1.33	e X	10.00	5.00	5.00	5.00	e X	1.00	8.00	8.00	7.33
Seine-Tancerville	e X	26.00	8.00	14.00	9.67	f X	1.00	1.00	1.00	1.33	X	12.00	13.00	34.00	20.67	X	52.00	11.00	17.00	14.33
Garonne-Bordeaux	e X	10.00	5.00	6.00	5.67	f X	10.00	1.00	3.00	1.67	X	10.00	3.00	X	X	X	1.00	6.00	3.00	4.33
Rhine-Selz	X	9.30	12.50	3.20	6.03	X	1.00	0.80	2.00	0.53	X	9.00	16.00	7.60	11.50	X	11.30	15.90	5.10	7.80
Germany, Fed Rep																				
Rhine-Bimmen	X	24.00	7.00	8.00	9.67	X	2.40	1.30	0.40	0.73	X	40.00	19.00	9.00	11.33	X	24.00	16.00	19.00	18.33
Italy																				
Po	d X	0.40	0.55	X	0.27	a X	X	0.05	X	0.06	d X	X	0.60	X	X	d X	0.60	0.85	X	0.91
Netherlands																				
Meuse-Keizersveer	X	12.00	12.00	6.00	7.00	X	0.90	1.50	0.40	0.53	X	7.00	7.00	5.00	5.00	X	9.00	12.00	7.00	6.33
Meuse-Eijsden	X	17.00	23.00	12.00	17.00	X	3.10	3.40	1.40	1.77	X	14.00	10.00	9.00	11.67	X	16.00	11.00	8.00	9.00
Scheur-Maasluis	X	13.00	11.00	2.00	4.33	X	1.00	0.90	0.50	0.67	X	16.00	19.00	6.00	7.00	X	15.00	12.00	6.00	7.33
Ijssel-Kampen	X	17.00	9.00	5.00	5.67	X	1.40	1.30	0.40	0.70	X	25.00	14.00	7.00	8.67	26.00	16.00	9.00	7.00	7.67
Norway																				
Skienselva	c X	1.00	1.00	X	X	c X	1.00	1.00	X	X	X	X	X	X	X	X	4.00	X	X	X
Portugal																				
Tejo	c X	X	50.00	X	X	c X	X	10.00	X	X	c X	X	10.00	X	X	X	X	X	X	X
Spain																				
Guadalaviar	X	20.00	12.70	X	12.00	X	X	X	X	X	X	X	10.00	X	21.20	X	X	2.70	X	7.83
Sweden																				
Dalalven	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	17.00	17.00	16.00
Switzerland																				
Rhine-Village	X	1.60	1.40	1.10	1.60	X	0.08	0.14	0.05	0.09	X	1.30	2.00	0.70	1.70	X	1.80	4.20	3.60	4.63
Aare-Brugg	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Limmat-Baden	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rhone-Port du Sceaux	X	X	3.38	2.13	2.68	X	X	X	X	X	X	X	X	X	X	X	X	3.48	3.82	4.62
United Kingdom																				
Thames	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Severn	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Clyde	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mersey	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Yugoslavia																				
Dunav	X	4.41	29.98	X	33.73	X	0.21	6.00	X	6.36	X	X	X	X	X	X	1.39	117.90	X	53.27
Drava	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Source: Organization for Economic Cooperation and Development.
0 = zero or less than one-half the unit of measure; X = not available.
a = total concentrations; b = orthophosphate concentrations; c = data represent upper limit (actual averages are lower);
d = dissolved concentrations; e = 1975 data represent upper limit; f = data for 1975 and 1980 represent upper limit.
For additional information, see Sources and Technical Notes.

Table 9.3 MAJOR RIVER BASINS

	Countries	Basin Area (1000 square kilometers)	Length (kilometers)	Average Annual Discharge (cubic kilometers per year)	Average Annual Suspended Sediment (million metric tons per year)
Amazon	Bolivia, Brazil, Ecuador, Colombia, Peru, Venezuela	7050	6280	3768	363
Zaire (Congo)	Angola, Congo, Zaire, Cameroon, Central African Republic	3691	4200	1256	65
Mississippi-Missouri	United States, Canada	3221	6019	556	365
Paraná	Argentina, Paraguay, Brazil, Bolivia	3103	4500	493	82
Nile	Uganda, Kenya, Zaire, Ethiopia, Tanzania, Sudan, Egypt, Rwanda, Burundi	2849	6671	81	111
Chang Jiang (Yangtze Kiang)	China	1807	6300	688	501
Niger	Cameroon, Guinea, Benin, Chad, Ivory Coast, Nigeria, Niger, Mali, Burkina Faso	1502	4160	224	5
Indus	Pakistan, India, Afghanistan, China	963	3180	443	436
Brahmaputra	Bangladesh, India, China, Bhutan	935	2900	476	726
Orinoco	Venezuela, Colombia, Brazil	906	2736	538	87
Mekong	China, Thailand, Lao PDR, Dem Kampuchea, Viet Nam, Burma	811	4500	538	170
Huang (Yellow)	China	684	5464	104	1600
Ganges	India, Bangladesh, Nepal, China, Bhutan	489	2700	440	1455
Irrawaddy	Burma, China, India	431	2293	443	299

Sources: U.S. Geological Survey; Rand McNally; American Society of Agronomy; Soil Science Society of America; The World Bank.
For additional information, see Sources and Technical Notes.

Table 9.4 FLOODS AND CYCLONES IN SELECTED COUNTRIES, 1960–81

	Floods			Cyclones	
	Number of Events	Deaths		Number of Events	Deaths
Brazil	28	2650	Philippines	39	5650
India	28	14700	Bangladesh	37	386200
Indonesia	23	1200	India	26	24930
Bangladesh	17	39900	Mexico	14	1560
Bolivia	13	160	Korea, Rep	10	700
Philippines	13	1400	Madagascar	9	970
Algeria	12	190	China	7	170
Mexico	11	370	Hong Kong	7	510
Colombia	10	600	Mauritius	7	15
Argentina	9	200	Burma	7	1350
Korea, Rep	9	1950	Haiti	6	5800
Peru	9	350	Viet Nam	6	7480
Viet Nam	9	350	French Caribbean	5	100
Costa Rica	8	30			
Morocco	8	90			
Burma	7	140			
Ecuador	7	20			
Lao People's	7	400			
China	6	1650			
Iran	6	350			
Mozambique	6	850			
Nepal	6	1500			
Pakistan	6	2100			
Panama	6	100			
Sri Lanka	6	100			
Tunisia	6	700			
South Africa	5	280			
Tanzania	5	65			

Source: League of Red Cross and Red Crescent Societies; U.S. Office of Foreign Disaster Assistance.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 9.1 Freshwater Availability and Use, 1970s

Source: J. Forkasiewicz and J. Margat, *Tableau Mondial de Données Nationales D'économie de l'Eau, Ressources et Utilisation* (Departement Hydrogéologie, Orléans, France, 1980).

The amount of water available to a country depends on the amount of precipitation (less evapotranspiration), and its distribution as runoff or groundwater storage. In this table, availability refers to stable streamflow or stable runoff—the base flow of rivers supplied by groundwater—and excludes flood waters and deep ground aquifers. It usually includes both internal and transit sources.

These data are annual averages and do not indicate peak flows or drought periods. Data for small countries and arid and semiarid zones are considered less reliable than the data for larger and wetter countries. Population estimates for the same year as the "Year of Information" were used to calculate per capita availability and withdrawals. If no "Year of Information" data were available, the 1975 population was used to calculate per capita statistics. For 1985 per capita availability data, see Part II, Chapter 8, "Freshwater," Table 8.3.

Water is *withdrawn* when it is taken from a surface or underground source and conveyed to the place of use. Water is *consumed* when it is no longer available for use because it has been removed from available supplies by evaporation or transpiration, by use in agriculture or manufacturing, or for human consumption. The amount of water withdrawn per person was calculated by dividing the estimated total withdrawal by the total population for that year.

Water use is generally classified in four categories: public supplies (principally for use in homes and commercial establishments), agriculture (principally for use in irrigation), industry (self-supplied use), and thermoelectric cooling (principally for use in cooling fossil fuel and nuclear power plants).

Because not all countries use these categories, the sectoral data are not strictly comparable. Data were included in the table if statistics for two or more sectors were available from the source document.

Omitted are instream uses of water such as hydroelectric power generation, navigation, habitat for fish and other aquatic life, and recreation.

For additional information on water resources, see M.I. L'vovich, *World Water Resources and Their Future* (Mysl' P.H. Moscow, 1974); English translation edited by Raymond L. Nace (American Geophysical Union, 1979).

Table 9.2 Water Quality, Selected Rivers, 1970–83

Source: Organization for Economic Cooperation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985), pp. 54–59.

The data in this table were collected from OECD member countries using questionnaires. Countries were asked to submit data that could be used to assess trends in water quality in major rivers over the years 1970 to 1983. For each river an attempt was made to monitor the ambient concentration of a pollutant (or the effects of pollutants) at a site at the mouth or the downstream frontier of the river. The OECD notes in the *Compendium* that these data should be used to compare trends within countries rather than between countries because monitoring methods vary from country to country. Data acceptable to OECD were compiled for 39 rivers (or river segments) in 18 member countries.

In a few cases data shown for 1970, 1975, and 1980 may represent data for adjacent years.

All data for the Waikato River in New Zealand are approximate.

Data for the Brisbane Estuary in Australia may not be comparable because measurements were made by different authorities. Data for 1972–75 are not comparable with those of later years because of different monitoring methods.

Table 9.3 Major River Basins

Sources: River length and country listing: Rand McNally, *The Great Geographic Atlas* (Rand McNally, Chicago, New York, San Francisco, 1982). Basin area and annual discharge: U.S. Geological Survey (USGS), *Water Quality and Availability* (USGS, Washington, unpublished manuscript, December 1983). Suspended load for Chang Jiang, Indus, and Paraná rivers: Alfredo Sfeir-Younis, *Soil Conservation in Developing Countries* (The World Bank, Washington, unpublished manuscript, 1985). Suspended load for all other rivers: S.A. El-Swaify and E.W. Dangler, "Rainfall Erosion in the Tropics: A State-of-the-Art," in *Soil Erosion and Conservation in the Tropics* (American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, 1982).

Rivers were chosen on the basis of basin area size. Omitted were those with relatively little human impact (Amur, USSR; Ob, USSR; Yenisey, USSR; Yukon, United States; Nelson, Canada), or for which comparable data were not available.

River length refers to the longest branch of the river, not necessarily the length of the main stream.

Both El-Swaify and Sfeir-Younis base their sediment analyses on data from J.N. Holeman, "The Sediment Yield of Major Rivers of the World," *Water Resources Research* (Soil Conservation Service, Washington, D.C., 1968). Both analysts have modified Holeman's data extensively. Many of the original data were derived from brief periods of sediment sampling during the 1930s, 1940s, and 1950s.

Table 9.4 Floods and Cyclones in Selected Countries, 1960–81

Source: Gunnar Hagman, *et al.*, *Prevention Better Than Cure, Report on Human and Environmental Disasters in the Third World* (The Swedish Red Cross, Stockholm, 1984).

Data on flood and cyclone disasters are compiled by the League of Red Cross and Red Crescent Societies and the U.S. Department of State, Office of Foreign Disaster Assistance (OFDA).

The League maintains a List of Major Appeals and Relief Actions that include events that were subject to major Red Cross or Red Crescent actions from 1919 to the present. The records include information about the date and location of the disaster, and the amount of aid donated for relief. The League recorded 389 disasters from 1960 to 1981.

The OFDA maintains a Disaster History List that provides information on: the date, location, and type of event; the number of persons killed, affected, injured, and homeless; and, for some events, damage estimates in U.S. dollars. Using records dating back to 1900, the OFDA has recorded over 1,622 disasters through 1981. Because there are wide discrepencies in the data prior to 1960, only 1960–81 data are used. Data for the developed countries are not included.

The League and OFDA have comparable records of 227 disaster events from 1960 to 1981. Both sources also have listings of many additional events that are not comparable; these are excluded from this table.

Only those countries that suffered five or more disasters during 1961–81 are listed in the table. The data are believed to underrepresent Africa.

10. Oceans and Coasts

The tables in this section provide information on national claims to coastal resources, fish catch, tropical coastal resources, and marine pollution.

Table 10.1 presents information on the length of coastlines, jurisdictional claims to coastal waters, and annual marine fish catch by country. Three types of jurisdictional claims are covered: territorial seas, Exclusive Economic Zones (EEZs), and continental shelves. Territorial seas are areas claimed by a country as sovereign territory. EEZ and continental shelf claims are economic in nature—claims to living and non-living resources. The past 11 years—since the Third U.N. Conference on the Law of the Sea began in 1974—have seen a remarkable transition in control over coastal resources as more than 50 countries have established EEZs. A significant part of the coastal seas, once a global commons, has come under the authority of nation states in this short time.

Marine fish harvests, also shown in Table 10.1, include national totals averaged over a two-year period. These totals include fish caught by a country's fleet anywhere in the world. Japan, for example, took 45 percent of its 1982 catch from the nearby Northwest Pacific fishery and the remainder from 16 of the other 17 marine fishery areas around the world.

Harvests from most of the world's marine fisheries, shown in Table 10.2, have changed in the last decade. The catch from the three Antarctic fisheries has increased markedly, although it remains small in absolute terms. The harvest from the Northwest Pacific fishery, source of 30 percent of the world's marine catch, grew by 24 percent, with most of the growth coming from increased harvests of herring, sardines, anchovies, and related species. The second largest fishery, the Northeast Atlantic, experienced little change.

The U.N. Food and Agriculture Organization (FAO) compiles fishery statistics in cooperation with regional fishery commissions and national governments. Several problems, however, hamper the collection and analysis of these data. First, the diversity of species within a fishery makes classification of the catch by species group difficult, especially for tropical fisheries. As a result, a large fraction of the catch is labeled "miscellaneous," which prevents marine scientists from assessing the sustainable yield of a particular species or fishery. Second, it is believed that the overall quality of the data has declined over the past 10–15 years. In the 1960s, regional fishery commissions played an active role in collecting and checking data, while the FAO performed the same functions at the global level. As more fishery areas came under national jurisdiction, the influence of regional fishery commissions declined, but without a commensurate strengthening of national fishery offices. At the same time, FAO's fishery statistics staff was cut.

Management agreements also affect data collection. Catch quotas can be an incentive for underreporting at the local level and at the national level when several nations share a managed fishery.

The latest information available on the extent and length of three important coastal resources—mangrove forests, coral reefs, and seagrass beds—is presented in Table 10.3. Found principally in the tropics, these salt-tolerant ecosystems provide valuable goods and services: they stabilize coastlines, dissipate wave energy, buffer salinity changes in coastal waters, retain sediments and nutrients, and support fisheries and tourism.

Data for Table 10.3 are preliminary estimates gathered from recent assessments, maps, and a questionnaire sent to country and regional experts. Because there has been no systematic monitoring of tropical coastal resources, the data base required to fully analyze trends in the extent, use, and condition of these resources does not exist.

A number of kinds of pollution can seriously damage renewable coastal resources and threaten the health of residents, visitors, and all who eat marine organisms. These pollutants include sediments, heavy metals, organochlorine compounds, petroleum hydrocarbons, sewage, and radioactive and other industrial, agricultural, and domestic effluents.

Each type of pollution tends to have a distinct effect on different ecosystems. Oil spills, for example, can seriously degrade beaches and harm waterfowl; sedimentation and organic wastes are particularly harmful to coral reefs.

Time series data on one of these pollutants, petroleum from tanker spills, are provided in Table 10.4.

The amount of oil spilled into the oceans during the early 1980s is substantially less than that spilled in the late 1970s. However, one large accident can distort the year-to-year trends. For example, in 1983, the *Castello de Belver*, a Spanish tanker, spilled 255,525 metric tons of petroleum off the coast of South Africa—two thirds of all the oil spilled that year.

Table 10.1 COASTAL AREAS AND RESOURCES, 1972–83

	Length of Marine Coastline (kilometers)	Maritime Zones (nautical miles unless indicated otherwise)			Average Annual Marine Fish Catch	
		Territorial Sea	Exclusive Economic Zone	Continental Shelf	1982-83 (thousand metric tons)	Percent Change Over 1972-73
WORLD						
AFRICA						
Algeria	1183	12	X	X	67	126
Angola	1600	20	X	200	104	-81
Benin	121	200	X	X	4	-60
Botswana	0	NA	NA	NA	0	NA
Burkina Faso	0	NA	NA	NA	0	NA
Burundi	0	NA	NA	NA	0	NA
Cameroon	402	50	X	X	42	141
Cape Verde	965	12	200	X	12	92
Central African Rep	0	NA	NA	NA	0	NA
Chad	0	NA	NA	NA	0	NA
Comoros	340	12	200	X	4	33
Congo	169	200	X	X	19	22
Djibouti	314	12	200	X	0	184
Egypt	2450	12	X	200m/EXP	25	-25
Equatorial Guinea	296	12	200	X	3	-38
Ethiopia	1094	12	X	X	0	-99
Gabon	885	100	X	X	50	1011
Gambia	80	12	X	X	8	6
Ghana	539	200	X	100f	192	-11
Guinea	346	12	200	X	17	121
Guinea-Bissau	274	12	200	X	3	93
Ivory Coast	515	12	200	200	78	16
Kenya	536	12	200	200m/EXP	7	15
Lesotho	0	NA	NA	NA	0	NA
Liberia	579	200	X	X	10	87
Libya	1770	12	X	X	7	182
Madagascar	4828	12	200	150	11	-25
Malawi	0	NA	NA	NA	0	NA
Mali	0	NA	NA	NA	0	NA
Mauritania	754	70	200	200/CM	45	47
Mauritius	177	12	200	200/CM	10	47
Morocco	1835	12	200	X	400	25
Mozambique	2470	12	200	X	36	204
Niger	0	NA	NA	NA	0	NA
Nigeria	853	30	200	200m/EXP	357	56
Rwanda	0	NA	NA	NA	0	NA
Senegal	531	12	200	200/CM	213	-19
Sierra Leone	402	200	X	200m/EXP	37	-37
Somalia	3025	200	X	X	15	99
South Africa	2881	12	X	200m/EXP	611	-5
Sudan	853	12	X	200m/EXP	3	525
Swaziland	0	NA	NA	NA	0	NA
Tanzania, United Rep	1424	50	X	X	30	12
Togo	56	30	200	X	12	61
Tunisia	1143	12	X	X	65	119
Uganda	0	NA	NA	NA	0	NA
Zaire	37	12	X	X	1	-93
Zambia	0	NA	NA	NA	0	NA
Zimbabwe	0	NA	NA	NA	0	NA
NORTH AMERICA						
Barbados	97	12	200	X	5	104
Canada	90908	12	X	200m/EXP	1316	22
Costa Rica	1290	12	200	200m/EXP	10	-3
Cuba	3735	12	200	X	183	27
Dominican Rep	1288	6	200	200/CM	11	70
El Salvador	307	200	X	X	10	-6
Guatemala	400	12	200	200m/EXP	4	21
Haiti	1771	12	200	200m/EXP	4	19
Honduras	820	12	200	200m/EXP	7	51
Jamaica	1022	12	X	200m/EXP	8	-15
Mexico	9330	12	200	200m/EXP	1180	178
Nicaragua	910	200	X	X	4	-59
Panama	2490	200	X	X	139	79
Trinidad and Tobago	362	12	X	200m/EXP	4	16
United States	19924	3	200	200m/EXP	3991	48
SOUTH AMERICA						
Argentina	4989	200	X	200m/EXP	431	79
Bolivia	0	NA	NA	NA	0	NA
Brazil	7491	200	X	X	634	11
Chile	6435	3	X	350	3825	423
Colombia	2414	12	200	200m/EXP	17	-42
Ecuador	2237	200	X	200m	481	267
Guyana	459	12	X	200/CM	26	42
Paraguay	0	NA	NA	NA	0	NA
Peru	2414	X	X	200	2465	-30
Suriname	386	12	200	X	3	-18
Uruguay	660	200	X	200m/EXP	131	590
Venezuela	2800	12	200	200m/EXP	202	35

Table 10.1

	Length of Marine Coastline (kilometers)	Maritime Zones (nautical miles unless indicated otherwise)			Average Annual Marine Fish Catch	
		Territorial Sea	Exclusive Economic Zone	Continental Shelf	1982–83 (thousand metric tons)	Percent Change Over 1972–73
ASIA						
Afghanistan	0	NA	NA	NA	0	NA
Bahrain	161	X	X	X	7	344
Bangladesh	580	12	200	X	143	63
Bhutan	0	NA	NA	NA	0	NA
Burma	3060	12	200	200/CM	447	34
China	14500	12	X	X	3369	22
Cyprus	648	12	X	200m/EXP	2	23
India	7000	12	200	200/CM	1501	38
Indonesia	54716	12	200	X	1538	79
Iran	3180	12	X	X	33	95
Iraq	58	12	X	X	9	149
Israel	273	6	X	200m/EXP	10	−24
Japan	13685	12	X	X	10789	11
Jordan	26	3	X	X	0	−82
Kampuchea, Dem	443	12	200	200m/EXP	5	−67
Korea, Dem Peoples Rep	2495	X	200	X	1488	79
Korea, Rep	2413	12	X	X	2295	72
Kuwait	499	12	X	X	4	−6
Lao People's Dem Rep	0	NA	NA	NA	0	NA
Lebanon	225	6	X	X	1	−36
Malaysia	2068	12	X	200m/EXP	696	75
Mongolia	0	NA	NA	NA	0	NA
Nepal	0	NA	NA	NA	0	NA
Oman	2092	12	200	X	99	−45
Pakistan	1046	12	200	200/CM	281	42
Philippines	22540	X	200	EXP	1265	19
Qatar	563	3	X	X	2	6
Saudi Arabia	2510	12	X	X	26	5
Singapore	193	3	X	X	19	16
Sri Lanka	1340	12	200	200/CM	186	99
Syrian Arab Rep	193	35	X	X	1	3
Thailand	3219	12	X	200m/EXP	2043	32
Turkey	7200	6	X	X	498	209
United Arab Emirates	1448	3	X	X	72	67
Viet Nam	3444	12	200	200/CM	473	−43
Yemen	523	12	X	X	13	36
Yemen, Dem	1383	12	200	200/CM	72	156
EUROPE						
Albania	418	15	X	200m/EXP	4	0
Austria	0	NA	NA	NA	0	NA
Belgium	64	3	X	X	48	−14
Bulgaria	354	12	X	200m/EXP	104	4
Czechoslovakia	0	NA	NA	NA	0	NA
Denmark	3379	3	X	200m/EXP	1871	30
Finland	1126	4	X	200m/EXP	118	56
France	3427	12	200	200m/EXP	765	−3
German Dem Rep	901	3	X	200m/EXP	218	−35
Germany, Fed Rep	1488	3	X	200m/EXP	287	−34
Greece	13676	6	X	200m/EXP	89	1
Hungary	0	NA	NA	NA	0	NA
Ireland	1448	3	X	X	208	128
Italy	4996	12	X	200m/EXP	437	10
Luxembourg	0	NA	NA	NA	0	NA
Malta	140	12	X	200m/EXP	1	−22
Netherlands	451	12	X	200m/EXP	500	46
Norway	3419	4	200	200m/EXP	2642	−12
Poland	491	12	X	200m/EXP	643	19
Portugal	860	12	200	200m/EXP	250	−46
Romania	225	12	X	200m/EXP	184	229
Spain	4964	12	200	200m/EXP	1286	−16
Sweden	3218	12	X	200m/EXP	253	17
Switzerland	0	NA	NA	NA	0	NA
United Kingdom	12429	3	X	200m/EXP	871	−21
Yugoslavia	1521	12	X	200m/EXP	47	53
USSR	**46670**	**12**	**200**	**200m/EXP**	**9057**	**24**
OCEANIA						
Australia	25760	3	X	200m/EXP	168	40
Fiji	1129	12	200	200m/EXP	26	456
New Zealand	15134	12	200	200/CM	130	110
Papua New Guinea	5152	12	X	200m/EXP	1	−96
Solomon Islands	5313	12	200	X	40	400
ANTARCTICA						

Sources: U.S. Department of State; U.N. Law of the Sea Secretariat; U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = no claim made or information not available; NA = not applicable; m = meters of water (depth); f = fathom (1.83 meters);
CM = edge of continental margin; EXP = limits of exploitable resources.
For additional information, see Sources and Technical Notes.

Table 10.2 MARINE FISHERY PRODUCTION BY SPECIES GROUP, 1972-83

	Average Annual Catch (thousand metric tons)		Share of Catch (percent)		Change in Catch 1982-83 over 1972-73 (percent)
	1972-73	1982-83	1972-73	1982-83	
ALL MARINE FISHERIES					
Total catch	**57853**	**67822**			**17**
Atlantic Northwest					
Total catch	4395	2755	100	100	-37
Cods, hakes, haddocks	1461	921	33	33	-37
Herrings, sardines, anchovies	852	497	19	18	-42
All others	2082	1337	47	49	-36
Atlantic Northeast					
Total catch	10990	10946	100	100	0
Cods, hakes, haddocks	4001	3786	36	35	-5
Jacks, mullets, sauries	2154	2340	20	21	9
All others	4836	4820	44	44	0
Atlantic, Western Central					
Total catch	1439	2212	100	100	54
Herrings, sardines, anchovies	625	1039	43	47	66
Redfishes, basses, congers	200	154	14	7	-23
Oysters	151	228	10	10	51
All others	463	791	32	36	71
Atlantic, Eastern Central					
Total catch	3283	3189	100	100	-3
Herrings, sardines, anchovies	1058	856	32	27	-19
Jacks, mullets, sauries	651	577	20	18	-11
All others	1575	1757	48	55	12
Mediterranean and Black Sea					
Total catch	1160	1885	100	100	62
Herrings, sardines, anchovies	502	957	43	51	91
Miscellaneous marine fishes	127	144	11	8	13
Jacks, mullets, sauries	97	165	8	9	70
All others	434	619	37	33	43
Atlantic, Southwest					
Total catch	875	1537	100	100	81
Herrings, sardines, anchovies	218	245	25	15	13
Redfishes, basses, congers	192	263	22	17	37
Cods, hakes, haddocks	162	567	18	36	251
All others	304	512	35	32	69
Atlantic, Southeast					
Total catch	3087	2354	100	100	-24
Cods, hakes, haddocks	1014	462	33	20	-54
Herrings, sardines, anchovies	1178	728	38	31	-38
Jacks, mullets, sauries	449	783	15	33	74
All others	446	380	14	16	-15
Atlantic, Antarctic					
Total catch	1	384	100	100	26409
Redfishes, basses, congers	1	114	100	30	7783
Krill, planktonic crustaceans	0	254	0	66	NM
All others	0	16	0	4	NM
Indian Ocean, Western					
Total catch	1827	2108	100	100	15
Miscellaneous marine fishes	457	231	25	11	-49
Herrings, sardines, anchovies	314	440	17	21	40
Redfishes, basses, congers	271	447	15	21	65
All others	786	990	43	47	26
Indian Ocean, Eastern					
Total catch	848	1716	100	100	102
Miscellaneous marine fishes	462	794	54	46	72
Redfishes, basses, congers	86	159	10	9	84
Herrings, sardines, anchovies	69	167	8	10	142
All others	231	596	27	35	159
Indian Ocean, Antarctic					
Total catch	63	145	100	100	130
Redfishes, basses, congers	58	30	93	21	-48
Miscellaneous marine fishes	5	0	7	0	-96
Krill, planktonic crustaceans	0	114	0	79	NM
All others	0	0	0	0	NM
Pacific, Northwest					
Total catch	16785	20770	100	100	24
Miscellaneous marine fishes	5273	4124	31	20	-22
Cods, hakes, haddocks	3471	3824	21	18	10
Herrings, sardines, anchovies	1133	4737	7	23	318
All others	6907	8085	41	39	17
Pacific, Northeast					
Total catch	2338	2326	100	100	-1
Cods, hakes, haddocks	1258	1341	54	58	7
Redfishes, basses, congers	269	142	12	6	-47
Salmons, trouts, smelts	184	351	8	15	90
All others	627	492	27	21	-22
Pacific, Western Central					
Total catch	4892	5996	100	100	23
Miscellaneous marine fishes	2041	1608	42	27	-21
Jacks, mullets, sauries	551	700	11	12	27
Tunas, bonitos, billfishes	449	910	9	15	103
All others	1850	2778	38	46	50
Pacific, Eastern Central					
Total catch	1255	1992	100	100	59
Tunas, bonitos, billfishes	338	364	27	18	8
Herrings, sardines, anchovies	301	982	24	49	226
All others	615	646	49	32	5
Pacific, Southwest					
Total catch	283	283	100	100	0
Tunas, bonitos, billfishes	73	41	26	15	-44
Redfishes, basses, congers	52	119	19	42	126
Squids, cuttlefishes, octopuses	8	74	3	26	845
All others	150	49	53	17	-67
Pacific, Southeast					
Total catch	4332	7032	100	100	62
Herrings, sardines, anchovies	3532	4597	82	65	30
Jacks, mullets, sauries	145	1951	3	28	1246
All others	655	484	15	7	-26
Pacific, Antarctic					
Total catch	0	9	NM	100	NM
Krill, planktonic crustaceans	0	9	NM	99	NM
All others	0	0	NM	1	NM

Source: U.N. Food and Agriculture Organization.

0 = zero or less than one-half the unit of measure; NM = not meaningful.
For additional information, see Sources and Technical Notes.

Table 10.3 TROPICAL COASTAL RESOURCES, EARLY 1980s

		Mangrove Forests			Seagrass Beds			Coral Reefs		
	Total Coastline (kilometers)	Area (square kilometers)	Length (kilometers)	Length as Percentage of Total Coastline	Area (square kilometers)	Length (kilometers)	Length as Percentage of Total Coastline	Area (square kilometers)	Length (kilometers)	Length as Percentage of Total Coastline
AFRICA										
Angola	1600	500	P	X	0	0	0	0	0	0
Benin	121	X	X	X	0	0	0	0	0	0
Cameroon	402	2720	125	31	0	0	0	0	0	0
Comoros	340	P	P	X	P	P	X	P	340	100
Congo	169	X	X	X	0	0	0	0	0	0
Djibouti[a]	314	P	P	X	P	P	X	P	P	X
Egypt (Red Sea, Gulfs of Aqaba and Suez)	1550	P	P	X	P	P	X	P	1100	80
Equatorial Guinea	296	X	X	X	0	0	0	0	0	0
Ethiopia	1094	P	P	X	P	P	X	P	321	29
Gabon	885	2500	P	X	0	0	0	0	0	0
Gambia	80	650	P	X	X	X	X	0	0	0
Ghana	539	X	X	X	0	0	0	0	0	0
Guinea	346	2600	P	X	0	0	0	0	0	0
Guinea-Bissau	274	2430	P	X	0	0	0	0	0	0
Ivory Coast	515	X	X	X	0	0	0	0	0	0
Kenya	536	587	P	X	P	P	X	P	400	75
Liberia	579	400	50	9	0	0	0	0	0	0
Madagascar	4828	3207	1150	24	P	P	X	P	P	X
Mauritania	754	X	X	X	X	X	X	0	0	0
Mauritius[b]	217	P	P	X	P	P	X	36273	210	97
Rodrigues Island[c]	40	X	X	X	X	X	X	200	60	150
Mozambique	2470	850	1194	48	P	P	X	2500	P	X
Namibia	1489	X	X	X	0	0	0	0	0	0
Nigeria	853	9730	P	X	0	0	0	0	0	0
Reunion	201	X	X	X	0	0	0	P	P	X
Sao Tome	209	X	X	X	0	0	0	P	P	X
Senegal	531	4400	40	8	X	X	X	0	0	0
Seychelles[b]	491	P	P	X	P	P	X	20093	245	50
Sierra Leone	402	1000	P	X	0	0	0	0	0	0
Somalia	3025	P	P	X	P	P	X	P	P	X
South Africa	2881	11	P	X	P	P	X	P	P	X
Sudan	853	P	P	X	P	P	X	P	963	113
Tanzania[d]	922	960	P	X	P	P	X	2183	750	81
Togo	56	X	X	X	0	0	0	0	0	0
Zaire	37	200	P	X	0	0	0	0	0	0
AMERICAS										
Bahamas	3542	P	P	X	38486	1638	46	P	1727	49
Belize[e]	386	2400	386	100	650	386	100	P	474	123
Bermuda	103	X	X	X	X	X	X	P	P	X
Brazil	7491	25000	P	X	P	P	X	P	P	X
Caymans	X	P	P	X	P	P	X	P	P	X
Colombia[f,g]	2414	4400	P	X	27327	1001	41	P	500	21
Costa Rica[f]	1290	390	210	16	2457	136	11	6	2.5	0.2
Cuba	3735	4000	P	X	42752	1092	29	P	1046	28
Dominican Republic	1288	90	P	X	3726	273	21	P	455	35
Ecuador	2237	2158	P	X	P	P	X	P	P	X
El Salvador	307	450	100	33	P	P	X	0	0	0
French Guiana	378	55	P	X	P	P	X	0	0	0
Guatemala	400	500	100	25	3312	182	46	0	0	0
Guyana	459	1500	P	X	P	P	X	0	0	0
Haiti	1771	180	P	X	P	P	X	P	182	10
Honduras[a,f]	820	3000	435	53	22362	546	67	P	364	44
Jamaica[d]	1022	70	P	X	327	273	27	P	442	43
Lesser Antilles[h]	2138	378	212	10	505	258	12	P	796	37
Mexico	10000	6600	P	X	P	1000	10	P	820	8
Netherlands Antilles[i]	364	5	22	6	36	53	14	P	172	47
Nicaragua[a,f]	910	600	700	77	28129	636	70	P	455	50
Panama[f,g]	2490	4860	880	35	9000	500	20	P	320	13
Peru	2414	280	P	X	X	X	X	0	0	0
Puerto Rico	498	65	P	X	828	91	18	P	182	36
Suriname	386	1150	P	X	P	P	X	0	0	0
Trinidad and Tobago	583	81	63	11	414	46	8	13	22	4
Turks and Caicos	351	P	P	X	P	P	X	P	P	X
US Gulf States	4800	2050	P	X	28393	2500	52	P	866	18
Venezuela[a]	2800	6736	1102	39	2542	288	10	P	227	8

(continued on next page)

Table 10.3 CONTINUED

		Mangrove Forests			Seagrass Beds			Coral Reefs		
	Total Coastline (kilometers)	Area (square kilometers)	Length (kilometers)	Length as Percentage of Total Coastline	Area (square kilometers)	Length (kilometers)	Length as Percentage of Total Coastline	Area (square kilometers)	Length (kilometers)	Length as Percentage of Total Coastline
ASIA										
Andaman and Nicobar Islands	500	100	300	60	P	P	X	P	325	65
Bahrain	161	P	P	X	P	P	X	P	P	X
Bangladesh	580	4050	P	X	P	P	X	0	0	0
Brunei	161	70	P	X	P	P	X	0	0	0
Burma	3060	5171	P	X	P	P	X	P	P	X
Chagos Archipelago	X	X	X	X	P	P	X	P	P	X
China[a]	14500	670	P	X	P	P	X	P	P	X
Hong Kong	733	X	P	X	P	P	X	0	0	0
India (Peninsular)	6000	3565	380	6.3	P	P	X	P	420	7
Indonesia	81000	36000	9696	12	P	P	X	P	17500	22
Iran[a]	3180	X	X	X	P	P	X	P	P	X
Iraq	59	X	X	X	P	P	X	0	0	0
Israel (Gulf of Aqaba)	10	X	X	X	X	X	X	P	9	90
Japan: Nansei Shoto	1500	X	X	X	P	P	X	P	1200	80
Jordan	26	X	X	X	P	P	X	P	13	50
Kampuchea, Dem	443	100	P	X	P	P	X	P	130	29
Kuwait	499	X	X	X	P	P	X	P	P	X
Laccadive Islands	500	X	X	X	P	P	X	P	P	X
Malaysia	4675	5700	2971	64	P	P	X	P	1670	36
Maldives	644	X	X	X	P	P	X	P	644	100
Oman	2092	P	84	4	P	P	X	P	625	30
Pakistan	1046	2495	P	X	P	P	X	0	0	0
Philippines	22450	1461	4009	18	P	P	X	P	22450	100
Qatar	563	X	X	X	P	P	X	P	P	X
Saudi Arabia	2510	X	X	X	X	X	X	P	1955	78
(Persian Gulf)	510	P	P	X	P	255	50	P	255	50
(Red Sea)	2000	P	700	35	P	700	35	P	1700	85
Singapore	193	12	58	30	P	P	X	P	26	14
Sri Lanka	1340	36	P	X	P	P	X	P	305	23
Taiwan	1240	1	P	X	P	P	X	P	190	15
Thailand	3219	2240	1805	56	P	P	X	P	900	28
United Arab Emirates	1448	30	P	X	P	P	X	P	P	X
Viet Nam[d]	3444	3200	P	X	P	P	X	X	X	X
Yemen	523	X	X	X	P	P	X	P	160	31
Yemen, Dem	1383	X	X	X	P	P	X	X	X	X
OCEANIA										
American Samoa[c]	419	P	P	X	X	X	X	P	628	150
Australia	25760	11617	P	X	P	P	X	P	3000	12
Cook Islands[c]	146	0	0	0	0	0	0	P	219	150
Federated States of Micronesia[c]	2610	P	P	X	P	P	0	P	3915	150
Fiji[c,j]	3640	433	P	X	P	P	X	P	5360	150
French Polynesia[c]	2525	0	0	0	X	X	X	P	3788	150
Guam	154	P	P	X	P	P	X	P	154	100
Hawaii	22085	P	P	X	P	P	X	P	P	X
Kiribati[c]	1143	P	P	X	0	0	0	P	1715	150
Marshall Islands[c]	1687	P	P	X	X	X	X	P	2531	150
Nauru	24	0.02	P	X	X	X	X	P	30	125
New Caledonia[c]	2254	200	P	X	P	P	X	P	3381	150
New Zealand	15134	198	P	X	X	X	X	0	0	0
Niue[c]	70	X	X	X	X	X	X	P	105	150
Northern Marianas	162	X	X	X	X	X	X	P	162	100
Palau[c]	500	P	P	P	P	X	X	P	750	150
Papua New Guinea	5152	4116	P	X	P	P	X	P	3684	72
Solomon Islands	5313	642	P	X	P	P	X	P	P	X
Tokelau[c]	10	X	X	X	X	X	X	P	15	150
Tonga[c]	419	10	P	X	X	X	X	P	628	150
Tuvalu[c]	24	X	X	X	X	X	X	P	36	150
Vanuatu[c]	2528	X	X	X	P	P	X	P	3792	150
Wallis and Futuna[c]	129	X	X	X	X	X	X	P	140	150
Western Samoa	488	P	P	X	X	X	X	P	P	X

Sources: World Resources Institute; International Institute for Environment and Development.
0 = zero or less than one-half the unit of measure; X = data not available; P = resource present but not quantified.
a = Includes offshore islands.
b = Figure for coral reefs includes banks.
c = Estimate of a 1.5 to 1 ratio of coral reef length to total coastline length based on measurements of the 107 major islands of Fiji and 27 volcanic and coral islands in eastern Polynesia.
d = Excludes offshore islands/islets.
e = Includes three major offshore atolls: Turneffe Islands, Lighthouse Reef, and Glovers Reef.
f = Does not include the Pacific coast seagrass beds.
g = Does not include the Pacific coast coral assemblages.
h = Includes the U.S. and British Virgin Islands except for Virgin Gorda; excludes Netherlands Antilles.
i = Resource data not available for Aruba and Bonaire.
j = Mangrove data for Viti Levu and Vanua Levu.
For additional information, see Sources and Technical Notes.

Table 10.4 ACCIDENTAL OIL SPILLS, 1973–85

Year	Number of Tankers Afloat	Accidental Oil Spills	Accidental Spills per Thousand Tankers	Oil Lost (metric tons)
1973	3750	36	9.6	84458
1974	3928	48	12.2	67115
1975	4140	45	10.9	188042
1976	4237	29	6.8	204235
1977	4229	49	11.6	213080
1978	4137	35	8.5	260488
1979	3945	65	16.5	723533
1980	3898	32	8.2	135635
1981	3937	33	8.4	45285
1982	3950	9	2.3	1716
1983	3582	17	4.7	387773
1984	3424	15	4.4	24184
1985[a]	3285	8	2.4	15000

Source: Tanker Advisory Center.
a = 1985 data have been estimated by annualizing trends of the first six months of the year.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 10.1 Coastal Areas and Resources, 1972–83

Sources: Length of marine coastline: U.S. Central Intelligence Agency, *The World Factbook 1983* (U.S. Government Printing Office, Washington, D.C., 1983). Jurisdictional and economic claims to maritime zones: Office of the Special Representative of the Secretary General for the Law of the Sea, *Law of the Sea Bulletin*, No. 2 (March 1985). Fish catch: U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics 1980* and *1983* (FAO, Rome, 1981 and 1985).

The Office of the Special Representative of the U.N. Secretary General for the Law of the Sea compiles information concerning coastal claims from the U.N. Legislative Series, official gazettes, communications to the Secretary General, legal journals, and other publications. National claims to maritime zones fall into five categories: territorial sea, contiguous zone, exclusive economic zone, fishery zone, and continental shelf claims.

Relevant legislation, decrees, and treaty commitments for 137 of the 141 coastal states are excerpted in the *Law of the Sea Bulletin*, with a note that information for 13 of them was taken from non-authoritative sources and confirmation of their accuracy and completeness was not always possible. The listing is changing as coastal countries seek to secure their claims to maritime resources under the Law of the Sea Convention.

"Territorial sea" commonly refers to an adjacent zone of water, seabed and subsoil, and airspace in which a nation claims sovereignty. The nation's right to enforce its laws and regulations is qualified only by the right of innocent passage of foreign ships. Nations may also claim certain jurisdictional rights in a contiguous zone beyond the territorial sea out to 24 nautical miles; these rights may pertain only to customs, taxation, immigration, and sanitation.

An Exclusive Economic Zone (EEZ) may be established by a nation out to 200 nautical miles to claim all the resources within the zone, including fish and all other living resources, minerals, energy from wind, waves, and tides, etc. Nations may also claim rights to regulate scientific exploration, protect the marine environment, and establish marine terminals and artificial islands.

Continental shelf claims include the exclusive right to explore for and exploit all mineral ores, energy resources, and benthic plants and animals that are found on or beneath the shelf. Claims are based on the distance from the shoreline (e.g. 200 nautical miles) and on the outer limit of the continental margin as defined in the 1982 convention.

International fishery data are under continual revision. The latest *Yearbook of Fishery Statistics* contains what FAO considers the most accurate and up-to-date figures.

Data are provided to the FAO Fisheries Department by national fishery offices and regional commissions. Some countries provide only provisional data for the latest year; others provide no data. If no new data are submitted, FAO uses the previous year's figures or prepares its own estimate based on other information.

Years refer to calendar years except for Antarctic fisheries data, which are for split years (July 1–June 30). Data for Antarctic fisheries are given for the calendar year in which the split year ends.

Catch refers to aquatic plants and animals killed, caught, trapped, collected, bred, or cultivated for commercial, industrial, and subsistence use. Quantities taken in recreational activities are excluded.

This table presents data on nominal catch, which is defined as gross removal (total live weight of fish caught or killed during fishing operations) minus pre-catch losses (total live weight of fish that are not caught but die in fishing operations), minus discarded catch both live and dead (undersized, unsalable, or otherwise undesirable whole fish discarded at the time of capture or shortly afterward), minus utilization and losses prior to landing (consumption by crew, use for bait, spoilage, handling losses), minus unrecorded, rejected, or dumped landings (unrecorded dumping at sea, black market landings, unrecorded quantities landed for home consumption, etc.), minus losses due to dressing, handling, and processing (dumped viscera, heads, and other parts, loss of fluids), plus gains prior to landing (gain of fluid content, addition of liquids or solids during shipboard processing).

Table 10.2 Marine Fishery Production by Species Group, 1972–83

Sources: U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics 1978* and *1983* (FAO, Rome, 1980 and 1985).

The FAO divides the world's oceans into 18 distinct marine fisheries.

The FAO organizes catch data by 840 species items, which include species, genera, or families of aquatic plants and animals. These 840 species items are first aggregated into 51 groups of species and then into 9 divisions, recognized as the International Standard Statistical Classification of Aquatic Animals and Plants. The divisions are: freshwater fishes, diadromous fishes, marine fishes, crustaceans, mollusks, whales, seals and other aquatic mammals, miscellaneous aquatic animals, miscellaneous animal products, and aquatic plants.

The species groups shown in Table 10.2 are those with the largest two catches in 1972–73 and 1982–83. In many fisheries, the same two species groups were the leaders for both times; for others, one or both of the top species groups in 1972–73 fell below that level in 1982–83.

Table 10.3 Tropical Coastal Resources, Early 1980s

Source: Nora Berwick, *Tropical Nearshore Resources—Patterns, Processes, Policy, and Impacts* (World Resources Institute/International Institute for Environment and Development, unpublished, 1985).

Tropical coastal resources refer to mangrove, seagrass, and coral reef systems. Areas outside the tropics that have such resources (New Zealand, Japan, Bermuda, the U.S. states along the Gulf of Mexico, etc.) are included.

Figures in the table represent a bounded area where the resources are determined to be important no matter what the density of trees, grass blades, or coral. These delineated areas are quoted from the literature or planimetered from atlases.

Mangroves are defined as tidal forests of salt-tolerant, woody, seed-bearing plants ranging from shrubs to trees. They are found inland along rivers (riverine mangroves), in infrequently flooded inland pools (basin forests), along coasts and lagoons (fringing mangroves), and on low-lying nearshore islands (overwash forests) in the humid tropics.

Seagrass beds are seed-producing marine grasses of varying density with extensive, substrate binding root and rhizome systems.

Coral reefs, an ecosystem composed principally of stony or reef-building corals, are a dominant feature of the shallow coastal marine environment in almost all areas between 25°N and 25 S that are remote from major upwellings or inflows of freshwater.

Table 10.3 is based on estimates from publications, questionnaires completed by experts, and planimetering of maps. The data vary in quality and coverage since a global data base utilizing a systematic quantitative survey of the extent, use, and ecological condition of tropical coastal resources does not exist.

For the many Pacific island countries where there are no data on the extent of reef resources and where the reef is generally longer than the island coastline, the length of the coral reef is estimated at one and one-half times the length of the coastline. This estimate is based on calculations of the coastlines of 107 major islands of the 310 comprising Fiji and of the 27 volcanic and coral islands in eastern Polynesia.

For additional information on coral reefs, the three-volume *Directory of Coral Reefs*, prepared by the Conservation Monitoring Center, International Union for Conservation of Nature and Natural Resources in 1985, presents an overview of the distribution of reefs, an examination of their status and relevant conservation issues and legislation, detailed accounts of established and recommended protected reef areas and of reefs well known for their scientific, fisheries, or tourism value, and a comprehensive bibliography.

Table 10.4 Accidental Oil Spills, 1973–85

Source: Tanker Advisory Center, New York.

The Tanker Advisory Center compiles oil spill accident data from lists of insurance claims and other known accidents maintained by Lloyd's of London and Liverpool Underwriters. Data for the number of tankers afloat are taken from *The Tanker Register*, maintained by H. Clarkson and Co., London.

For 1973–82, data refer to tankers of at least 6,000 metric tons deadweight, and for 1983–85, to tankers of at least 10,000 metric tons deadweight. Vessels carrying liquefied gas are not included.

Spills refer to oil lost during accidents. Oil lost during cleaning and ballasting operations is not included.

11. Atmosphere and Climate

The quality of the atmosphere can be measured in three ways: the amounts of pollutants released; the ambient concentration of pollutants in air and precipitation; and the impact pollutants have on humans, other living organisms, materials and buildings, and natural systems, including climate. The tables in this chapter present data on pollutant emissions and ambient concentrations; impact data are not available on a comprehensive basis for most airborne pollutants. The growing amount of data being generated by the Global Environmental Monitoring System (GEMS) has been used in this edition of *World Resources* to highlight urban and regional conditions. Data from GEMS and other sources have been used to examine global atmospheric conditions.

Estimates of the amount of carbon emitted to the atmosphere from the combustion of fossil fuels are presented in Tables 11.1 and 11.2. These estimates, derived from energy production and consumption data, indicate an average annual growth rate in carbon emissions of about 4.4 percent per year from 1950 to 1973 and erratic growth averaging about 1.5 percent per year since 1973. Preliminary data indicate that the carbon emission rate turned sharply upward in 1984.

The geographical pattern of carbon emissions has changed as well. The United States was the source of 44 percent of global carbon emissions in 1950, but only 24 percent in 1983. Japan increased from 2 percent in 1950 to 5 percent in 1983, while China increased from 1 percent of the world total in 1950 to 9 percent in 1983.

The results of carbon dioxide monitoring at stations in remote locations are shown in Table 11.4. Since 1958, the global concentration of carbon dioxide has increased from 315 to 345 parts per million, an increase of about 10 percent. The concentration prior to widespread industrialization and land clearing has been estimated at about 275 parts per million.

Other gases have radiative properties similar to those of carbon dioxide. Chlorofluorocarbons, methane, and nitrous oxide (all of which may modify stratospheric ozone) are of increasing importance in evaluating "greenhouse" effects. Current research indicates that methane concentrations are increasing by about 1 percent per year; nitrous oxide concentrations by about 0.2 percent per year; and chlorofluorocarbon releases, after declining because of regulation and economic recession, are again increasing. The trend in chlorofluorocarbon releases is somewhat uncertain because emissions data are not available for the Soviet Union and several other countries.

Data for urban air quality in 62 cities in 43 countries are given in Tables 11.5 and 11.6. About one fourth of the sites report average annual concentrations of SO_2 that are above the upper guideline (40 to 60 micrograms per cubic meter ($\mu g/m^3$)) established by the World Health Organization (WHO) to protect long-term human health. Most of these sites are industrial and commercial and are located in urban centers. The 63 sites that have data for 5 or more years were used to analyze trends. These data indicate that air quality at 54 percent of the sites had improved during the period 1973-80; 30 percent reported no change; and 16 percent reported increased concentrations of SO_2.

In Table 11.6 the results of the two principal techniques used to monitor suspended particulate matter—high-volume sampling and smoke-shade sampling—are shown separately. The WHO guidelines to protect long-term health are 60–90 $\mu g/m^3$ for high-volume monitoring and 40–60 $\mu g/m^3$ for smoke-shade monitoring. About 40 percent of all sites are above the upper guideline. Forty-three percent of the sites recorded downward trends; 47 percent recorded no trend; and 10 percent recorded an upward trend.

Missing from this table are data for many large cities that are known to have serious air quality problems. These cities are omitted because they failed to accurately monitor these pollutants for the years indicated or they chose not to participate in the GEMS program. Internationally comparable data for carbon monoxide, photochemical oxidants, and lead—pollutants that can also cause serious health problems in urban areas—are not available.

The latest data on acid and ion deposition at sites around the world are provided in Table 11.7. Monitoring was conducted at locations far from human sources of air pollution to ensure that measured values represent regional or global background conditions, not local problems. A pH reading of approximately 5 or lower usually indicates the presence of excess acidity. The results indicate that even the remote areas of Northern and Central Europe, the eastern portion of North America, and Japan are receptors of anthropogenic acid precipitation.

Table 11.1 GLOBAL CARBON DIOXIDE EMISSIONS FROM ANTHROPOGENIC SOURCES, 1950–84

	Carbon Emissions (million metric tons of carbon)						
		Fossil Fuel Combustion				Other Industrial Sources	
	Total	Total	Solid Fuels	Liquid Fuels	Natural Gas	Gas Flaring	Cement Production
1950	1639	1598	1078	423	97	23	18
1951	1776	1731	1137	479	115	24	21
1952	1803	1755	1127	504	124	26	22
1953	1848	1797	1133	533	131	27	24
1954	1872	1818	1123	557	138	27	27
1955	2050	1990	1215	625	150	30	30
1956	2185	2121	1281	679	161	32	32
1957	2278	2209	1317	714	178	35	34
1958	2339	2268	1344	732	192	35	36
1959	2470	2394	1390	790	214	36	40
1960	2586	2504	1419	850	235	39	43
1961	2602	2515	1356	905	254	41	46
1962	2709	2616	1358	981	277	44	49
1963	2855	2756	1403	1053	300	47	52
1964	3016	2908	1442	1138	328	51	57
1965	3154	3040	1467	1221	352	55	59
1966	3313	3190	1485	1325	380	60	63
1967	3420	3288	1454	1424	410	66	66
1968	3595	3452	1455	1552	445	73	70
1969	3808	3654	1493	1674	487	80	74
1970	4116	3950	1595	1839	516	88	78
1971	4267	4093	1594	1946	553	90	84
1972	4435	4250	1612	2056	582	95	90
1973	4678	4470	1622	2240	608	112	96
1974	4684	4481	1620	2245	616	107	96
1975	4660	4468	1715	2132	621	96	96
1976	4924	4712	1754	2313	645	110	102
1977	5065	4848	1812	2390	646	108	109
1978	5108	4885	1828	2384	673	106	117
1979	5345	5152	1899	2538	715	74	119
1980	5255	5056	1924	2408	724	78	121
1981	5115	4935	1928	2274	733	58	122
1982	5079	4901	1983	2184	734	56	122
1983	5054	4880	1985	2164	731	52	122
1984p	5330	5155	2103	2268	784	47	128

Source: Institute for Energy Analysis, Oak Ridge Associated Universities.
p = preliminary.
For additional information, see Sources and Technical Notes.

Table 11.2 CARBON DIOXIDE EMISSIONS, BY COUNTRY AND REGION, 1950, 1965, AND 1983

	Carbon Emissions from Fossil Fuel Consumption														
	1950 (million metric tons of carbon)					1965 (million metric tons of carbon)					1983 (million metric tons of carbon)				
	Solid	Liquid	Gas	Total	Percentage of World Total	Solid	Liquid	Gas	Total	Percentage of World Total	Solid	Liquid	Gas	Total	Percentage of World Total
WORLD	**1072**	**385**	**96**	**1553**	**100.0**	**1464**	**1118**	**347**	**2929**	**100.0**	**2017**	**2028**	**738**	**4783**	**100.0**
North America	376	259	88	723	46.6	318	447	238	1003	34.2	432	553	260	1245	26.0
United States	347	245	87	679	43.7	301	406	228	935	31.9	405	500	233	1138	23.8
Canada	29	14	1	44	2.8	17	41	10	68	2.3	27	53	27	107	2.2
Western Europe	336	40	1	377	24.3	358	274	11	643	22.0	272	369	112	753	15.7
United Kingdom	125	11	X	136	8.8	117	52	<1	169	5.8	68	45	28	141	2.9
France	46	9	<1	55	3.5	49	42	3	94	3.2	30	59	14	103	2.2
Germany, Fed Rep	91	2	X	93	6.0	115	56	1	172	5.9	86	68	25	179	3.7
Italy	7	4	<1	11	0.7	8	37	4	49	1.7	12	65	14	91	1.9
Other	66	15	<1	81	5.2	68	87	2	157	5.4	75	131	32	238	5.0
Eastern Europe	250	36	5	291	18.7	495	174	79	748	25.5	609	405	265	1279	26.7
USSR	149	33	3	185	11.9	290	151	68	509	17.4	355	335	221	911	19.0
Poland	30	<1	<1	30	1.9	61	4	1	66	2.3	97	11	5	113	2.4
German Dem Rep	43	X	X	43	2.8	79	3	X	82	2.8	64	13	5	82	1.7
Other	28	3	2	33	2.1	66	16	10	92	3.1	93	45	34	172	3.6
Pacific	40	5	X	45	2.9	66	71	1	138	4.7	92	173	22	287	6.0
Japan	26	1	X	27	1.7	45	55	1	101	3.4	61	148	15	224	4.7
Other	14	4	X	18	1.2	21	16	X	37	1.3	31	25	7	63	1.3
Centrally Planned Asia	22	<1	X	22	1.4	134	11	1	146	5.0	403	73	6	482	10.1
China	21	X	X	21	1.4	120	10	1	131	4.5	365	69	6	440	9.2
Other	<1	X	X	X	X	14	2	X	16	0.5	38	4	X	42	0.9
Developing World	48	45	2	95	6.1	93	141	17	251	8.6	209	456	73	738	15.4
Latin America	6	29	1	36	2.3	8	68	11	87	3.0	18	171	35	224	4.7
Africa	19	7	X	26	1.7	34	20	1	55	1.9	66	67	10	143	3.0
Middle East	2	2	X	4	0.3	4	23	2	29	1.0	11	89	16	116	2.4
South and Southeast Asia	20	7	<1	27	1.7	47	29	3	79	2.7	114	129	11	254	5.3

Source: Institute for Energy Analysis, Oak Ridge Associated Universities.
X = not available.
For additional information, see Sources and Technical Notes.

Table 11.3 PRODUCTION AND RELEASE OF CHLOROFLUOROCARBONS, 1931–84

	CFC-11 (thousand metric tons)		CFC-12 (thousand metric tons)	
	Production	Release	Production	Release
1931	0.0	0.0	0.5	0.1
1936	0.1	0.0	1.7	0.5
1941	0.3	0.1	6.3	3.0
1946	0.7	0.6	16.6	13.9
1951	9.1	7.6	36.2	32.4
1956	32.5	28.7	68.7	56.1
1960	49.7	40.5	99.4	89.1
1961	60.5	52.1	108.5	99.7
1962	78.1	65.4	128.1	114.5
1963	93.3	80.0	146.4	133.9
1964	111.1	95.0	170.1	155.5
1965	122.8	108.3	190.1	175.4
1966	141.0	121.3	216.2	195.0
1967	159.8	137.6	242.8	219.9
1968	183.1	156.8	267.5	246.5
1969	217.3	181.9	297.3	274.3
1970	238.1	206.6	321.1	299.9
1971	263.2	226.9	341.6	321.8
1972	306.9	255.8	379.9	349.9
1973	349.1	292.4	423.3	387.3
1974	369.7	321.4	442.8	418.6
1975	314.1	310.9	381.0	404.1
1976	339.8	316.7	410.7	390.4
1977	320.5	303.9	382.8	371.2
1978	308.9	283.6	372.1	341.3
1979	289.5	263.7	357.2	337.5
1980	289.6	250.8	350.2	332.5
1981	286.9	248.2	351.3	340.7
1982	271.4	239.5	328.0	337.4
1983	291.7	252.8	355.3	343.3
1984	312.4	271.1	382.1	359.4

Source: Chemical Manufacturers Association.
0 = zero, or less than 90 metric tons.
For additional information, see Sources and Technical Notes.

Table 11.4 CARBON DIOXIDE IN THE ATMOSPHERE, 1958–85

	Average Annual Concentrations of Carbon Dioxide (parts per million, volume basis)							
	Barrow, Alaska (71°N)		Mauna Loa, Hawaii (20°N)		American Samoa (14°S)		South Pole (90°S)	
	Concentration	Annual Increase	Concentration	Annual Increase	Concentration	Annual Increase	Concentration	Annual Increase
1958	X	X	X	X	X	X	314.6	X
1959	X	X	316.1	X	X	X	315.4	0.9
1960	X	X	317.0	0.9	X	X	316.7	1.3
1961	X	X	317.7	0.7	X	X	317.5	0.8
1962	X	X	318.6	0.9	X	X	318.0	0.5
1963	X	X	319.1	0.5	X	X	318.2	0.2
1964	X	X	319.6	0.5	X	X	318.3	0.1
1965	X	X	320.4	0.8	X	X	319.3	1.0
1966	X	X	321.1	0.7	X	X	320.6	1.3
1967	X	X	321.8	0.7	X	X	221.2	0.6
1968	X	X	322.8	1.0	X	X	321.8	0.6
1969	X	X	324.2	1.4	X	X	322.6	0.7
1970	X	X	325.5	1.3	X	X	324.2	1.6
1971	X	X	326.5	1.0	X	X	325.0	0.8
1972	X	X	327.7	1.3	X	X	325.8	0.8
1973	X	X	329.7	2.0	X	X	327.4	1.7
1974	332.6	X	330.4	0.7	X	X	328.3	0.9
1975	333.4	0.8	331.0	0.6	X	X	329.3	1.0
1976	333.7	0.3	332.1	1.1	331.2	X	330.4	1.1
1977	334.6	0.9	333.6	1.5	332.6	1.4	331.9	1.4
1978	336.7	2.1	335.2	1.6	X	X	333.5	1.6
1979	337.9	1.2	336.6	1.4	336.1	X	334.9	1.3
1980	339.9	2.0	338.4	1.7	338.0	1.9	336.8	1.9
1981	341.7	1.8	339.5	1.1	339.2	1.2	338.1	1.3
1982	342.8	1.1	340.7	1.3	340.2	1.0	339.2	1.1
1983	343.8	1.0	342.7	2.0	341.4	1.2	341.0	1.8
1984	346.0	2.2	344.4	1.7	343.0	1.6	342.4	1.4
1985	X	X	345.6	1.3	X	X	X	X

Sources: Scripps Institution of Oceanography; U.S. National Oceanic and Atmospheric Administration.
X = not available.
For additional information, see Sources and Technical Notes.

Table 11.5 CONCENTRATIONS OF SULFUR DIOXIDE IN URBAN

	Number of Monitoring Sites	Site-Years	Average Annual Concentration (micrograms per cubic meter)				Average 1973–80	Range 1973–80	Trends in Concentration (percent per year)		
			1973–74	1975–76	1977–78	1979–80			Industrial Site	Commercial Site	Residential Site
AFRICA											
Egypt											
Cairo	3	2	X	65	X	X	65	61-69	X	X	X
Ghana											
Accra	3	X	X	X	X	X	X	X	X	X	X
Kenya											
Nairobi	2	X	X	X	X	X	X	X	X	X	X
NORTH AMERICA											
Canada											
Hamilton	2	10	X	53	43	35	42	32-57	X	-10	-9
Montreal	3	14	X	44	47	37	43	14-71	X	-5	-6
Toronto	3	15	X	31	27	21	25	18-35	-7	-11	-9
Vancouver	4	22	19	25	X	17	20	14-29	0	-9	-2
United States											
Birmingham	3	3	X	19	17*	X	18	6-32	X	X	X
Chicago	2	2	X	20*	X	48*	34	20-48	X	X	X
Houston	3	9	X	3	9	20*	9	3-20	X	X	X
Los Angeles	2	3	X	33	40*	X	35	27-40	X	X	X
New York City	3	6	X	X	X	59	59	43-80	X	X	X
St. Louis	5	11	X	91	68	40	59	25-149	X	X	X
LATIN AMERICA											
Brazil											
Rio de Janeiro	1	2	X	57*	128*	X	93	57-128	X	X	X
Sao Paulo	3	15	X	100	109	125	114	72-153	+1	+6	+10
Chile											
Santiago	3	7	X	60	66	58*	63	48-93	X	-4	+1
Colombia											
Bogota	3	2	X	18*	15*	X	17	15-18	-8	X	X
Cali	2	3	X	14	10*	X	12	6-21	X	X	X
Medellin	2	3	X	25*	16*	34*	25	16-34	X	X	X
Cuba											
Havana	3	9	X	46	38	X	41	22-66	X	X	X
Peru											
Lima	3	2	X	11*	X	3*	7	3-11	X	X	X
Venezuela											
Caracas	3	6	X	14	14	X	14	7-24	X	X	X
ASIA											
Hong Kong											
Hong Kong	3	18	X	33	28	45	35	5-100	+5	+70	+36
India											
Bombay	3	7	X	X	51	37	43	20-96	X	X	X
Calcutta	3	21	41	35	40	40	38	17-58	+2	0	-6
Delhi	3	9	X	X	33	33	33	8-58	X	X	X
Iran											
Teheran	3	11	X	84*	50	91	75	40-160	X	+12	X
Iraq											
Baghdad	3	X	X	X	X	X	X	X	X	X	X
Israel											
Tel Aviv	3	13	29	23	X	53*	28	16-54	X	X	X
Japan											
Osaka	4	23	X	65	50	38	51	29-74	-14	-14	-11
Tokyo	3	24	65	64	59	54	61	37-85	-4	-4	-2
Korea, Rep											
Seoul	3	X	X	X	X	X	X	X	X	X	X
Malaysia											
Kuala Lumpur	2	5	X	X	24	13	18	3-43	X	X	X
Pakistan											
Lahore	2	X	X	X	X	X	X	X	X	X	X
Philippines											
Manila	3	13	X	83	62	66	73	46-130	-3	+1	-2
Thailand											
Bangkok	2	X	X	X	X	X	X	X	X	X	X

AREAS, 1973–80

Table 11.5

	Number of Monitoring Sites	Site-Years	Average Annual Concentration (micrograms per cubic meter)				Average 1973–80	Range 1973–80	Trends in Concentration (percent per year)		
			1973–74	1975–76	1977–78	1979–80			Industrial Site	Commercial Site	Residential Site
EUROPE											
Belgium											
Brussels	3	22	111	91	78	77	88	60–121	-8	-4	-6
Czechoslovakia											
Prague	3	15	106	106	113	X	107	58–148	+2	+1	+1
Denmark											
Copenhagen	3	10	X	X	35	23	27	13–57	X	X	X
Finland											
Helsinki	3	9	X	X	27	28	28	24–33	X	X	X
France											
Paris	4	11	X	X	105	91	98	77–131	X	X	X
Toulouse	3	7	X	X	12	7	11	4–39	X	X	X
Germany, Fed Rep											
Frankfurt	3	11	97	90	79	76	88	74–109	-8	-6	X
Greece											
Athens	3	4	X	X	35	51	43	30–57	X	X	X
Ireland											
Dublin	3	12	X	X	35	35	35	21–56	X	X	X
Italy											
Milan	2	6	X	X	208	205	207	167–242	X	X	X
Rome	3	2	86	X	X	X	86	58–114	X	X	X
Netherlands											
Amsterdam	3	21	39	34	28	33	34	21–55	-4	-5	+1
Poland											
Warsaw	3	7	X	X	28*	40	39	28–47	X	X	X
Wroclaw	3	9	X	X	33	39	37	23–46	X	X	X
Portugal											
Lisbon	2	X	X	X	X	X	X	X	X	X	X
Spain											
Madrid	3	17	139	100	44*	65	100	30–193	-11	X	-8
Sweden											
Stockholm	5	12	X	X	35	38	36	16–60	0	+7	+2
Switzerland											
Zurich	1	X	X	X	X	X	X	X	X	X	X
United Kingdom											
Glasgow	3	8	X	X	82	66	76	44–94	X	X	X
London	3	18	107	100	78	81	92	56–149	-10	-9	-2
Yugoslavia											
Zagreb	3	24	104	87	73	55	79	33–195	-8	-9	-6
OCEANIA											
Australia											
Melbourne	1	5	X	14	21*	6	12	4–21	X	-17	X
Sydney	3	13	X	43	40	40	41	19–70	+1	-7	-10
New Zealand											
Auckland	3	12	X	12*	20	17	18	11–25	+7	+10	X
Christchurch	3	9	X	X	22	30	27	17–37	X	X	X

Sources: World Health Organization; United Nations Environment Program.
X = incomplete data; * = single year value only.
For additional information, see Sources and Technical Notes.

Table 11.6 CONCENTRATIONS OF SUSPENDED PARTICULATE

	Number of Monitoring Sites	Site-Years	Average Annual Concentration (micrograms per cubic meter)				Average 1973–80	Range 1973–80	Trends in Concentration (percent per year)		
			1973–74	1975–76	1977–78	1979–80			Industrial Site	Commercial Site	Residential Site
					High Volume Sampling Method						
AFRICA											
Ghana											
Accra	3	X	X	X	X	X	X	X	X	X	X
Kenya											
Nairobi	2	X	X	X	X	X	X	X	X	X	X
NORTH AMERICA											
Canada											
Hamilton	2	10	X	118	109	112	112	99–124	X	-1	+1
Montreal	3	14	X	84	71	72	73	64–92	X	X	-4
Toronto	3	15	X	74	71	84	77	66–99	+7	+3	-3
Vancouver	4	21	66	69	73	76	69	52–97	+5	0	-1
United States											
Birmingham	4	14	X	88	108	77	92	63–150	-2	0	X
Chicago	3	10	X	107	110	134	114	68–200	-7	X	X
Houston	3	10	X	83	102	86	95	70–115	X	X	X
Los Angeles	4	7	X	89	103	X	97	74–124	X	X	X
New York City	3	9	X	69	72	61	65	51–79	X	X	X
St. Louis	5	16	113	104	87	X	102	64–144	-3	X	X
ASIA											
India											
Bombay	3	7	X	X	279	193	229	136–466	X	X	X
Calcutta	3	24	389	422	364	427	396	292–547	-3	-1	-3
Delhi	3	9	X	X	389	422	411	305–535	X	X	X
Indonesia											
Jakarta	2	4	X	X	X	209	209	138–275	X	X	X
Iran											
Teheran	3	11	X	330*	393	336	356	285–459	-3	-3	+2
Iraq											
Baghdad	3	X	X	X	X	X	X	X	X	X	X
Japan											
Osaka	4	23	X	78	60	59	65	49–97	-1	-11	-6
Tokyo	3	24	66	65	57	58	61	48–77	-4	0	-5
Malaysia											
Kuala Lumpur	2	6	X	X	122	129	126	79–182	X	X	X
Pakistan											
Lahore	2	X	X	X	X	X	X	X	X	X	X
Philippines											
Iligan City	1	X	X	X	X	X	X	X	X	X	X
Manila	3	15	X	79	91	88	85	71–101	-3	X	+7
Thailand											
Bangkok	3	5	X	X	162*	171	169	162–176	X	X	X
EUROPE											
Czechoslovakia											
Prague	3	10	137	172	146	X	157	124–262	-4	-13	-4
Denmark											
Copenhagen	3	10	X	X	32	37	35	27–52	X	X	X
Finland											
Helsinki	3	9	X	X	89	94	92	52–163	X	X	X
Germany, Fed Rep											
Frankfurt	1	3	X	X	32	27*	30	27–33	X	-9	X
Greece											
Athens	3	3	X	X	225	X	225	204–255	X	X	X
Yugoslavia											
Zagreb	3	23	160	150	151	146	152	127–181	-2	-4	+1
OCEANIA											
Australia											
Melbourne	1	6	X	27	42	73*	42	24–73	X	-2	X
Sydney	3	15	X	97	92	94	93	72–156	-7	+4	0

MATTER IN URBAN AREAS, 1973–80

Table 11.6

	Number of Monitoring Sites	Site-Years	Average Annual Concentration (micrograms per cubic meter)				Average 1973–80	Range 1973–80	Trends in Concentration (percent per year)		
			1973–74	1975–76	1977–78	1979–80			Industrial Site	Commercial Site	Residential Site
Smoke Sampling Method											
AFRICA											
Egypt											
Cairo	3	4	X	67	56	X	61	47-70	X	X	X
LATIN AMERICA											
Brazil											
Rio de Janeiro	1	1	X	31*	X	X	31*	X	X	X	X
Sao Paulo	3	15	X	90	77	73	78	61-98	-5	-3	-4
Chile											
Santiago	3	7	X	68*	65	100*	70	25-115	X	+2	+3
Colombia											
Bogota	3	2	X	32*	24*	X	28	24-32	X	X	X
Cali	2	3	X	39	27*	X	35	22-55	X	X	X
Medellin	2	3	X	44*	21*	56*	40	21-56	X	X	X
Cuba											
Havana	3	9	X	45	47	X	46	25-61	X	X	X
Peru											
Lima	3	3	X	26*	21*	6*	18	6-26	X	X	X
Venezuela											
Caracas	3	6	X	22	22	X	22	14-31	X	X	X
ASIA											
Hong Kong											
Hong Kong	3	18	X	59	70	56	62	25-120	-1	-2	-1
Iran											
Teheran	3	12	X	232*	171	182	181	90-232	-2	-3	+4
EUROPE											
Belgium											
Brussels	3	22	29	26	19	19	23	11-38	-10	-6	-7
Denmark											
Copenhagen	3	12	X	X	11	15	13	8-24	X	X	X
France											
Paris	3	11	X	X	44	45	45	38-52	X	X	X
Toulouse	3	6	X	X	58	22	46	15-179	X	X	X
Ireland											
Dublin	3	12	X	X	32	22	27	14-43	X	X	X
Italy											
Rome	3	3	31*	51	X	X	44	22-80	X	X	X
Poland											
Warsaw	3	7	X	X	64*	49	51	40-64	X	X	X
Wroclaw	3	9	X	X	68	61	63	49-92	X	X	X
Spain											
Madrid	3	16	188	162	X	125	160	56-307	-10	-1	-6
United Kingdom											
Glasgow	3	8	X	X	29	30	30	20-42	X	X	X
London	3	19	33	34	26	43	33	20-84	+8	-8	-4
OCEANIA											
New Zealand											
Auckland	3	12	X	4*	5	5	5	4-9	-5	0	X
Christchurch	3	8	X	X	23	29	27	19-41	X	X	-9

Sources: World Health Organization, United Nations Environment Program
X = incomplete data; *= single year value only.
For additional information, see Sources and Technical Notes.

Table 11.7 PRECIPITATION CHEMISTRY MONITORING, 1975–82

	Average Annual pH				Average Annual Concentration of Sulfate (milligrams per liter)				Average Annual Concentration of Nitrate (milligrams per liter)			
	1975–76	1977–78	1979–80	1981–82	1975–76	1977–78	1979–80	1981–82	1975–76	1977–78	1979–80	1981–82
AFRICA												
Malawi												
Nkhome	X	X	X	X	X	X	X	0.70*	X	X	X	X
Tunisia												
Thala	X	X	6.7*	X	X	X	0.47*	X	X	X	0.01*	X
NORTH AMERICA												
Canada												
Edson	6.1*	5.8	5.9	6.4*	0.73*	0.71	0.52	0.64*	0.38*	0.16	0.20	0.21*
Kelowna	X	6.1	5.8	5.6*	X	0.58	0.41	0.25*	X	0.30	0.38	0.31*
Hay River	X	X	6.5*	6.7*	X	X	0.73*	0.65*	X	X	0.14*	0.10*
Maniwaki	4.6	4.3	4.3	4.2*	1.60	1.40	1.30	1.10*	0.64	0.57	0.61	0.61*
Mould Bay	X	6.5*	6.2*	5.5*	X	1.20	0.58*	0.65*	X	X	0.13*	0.05*
Mt. Forest	4.6	5.1	4.9	4.7*	1.40	2.60*	1.80	1.40*	0.69	1.30	0.84	0.64*
Pickle Lake	X	5.4	5.5	5.5*	X	0.70	0.61	0.99*	X	0.22	0.25	0.19*
Sable Island	4.9	4.8	5.1	5.1*	1.50	0.86	0.59	0.36*	0.26	0.13	0.20	0.10*
Wynyard	X	6.5	6.9	6.7*	X	0.83	1.20	0.69*	X	0.51	1.00	0.35*
El Salvador												
Cerro Verde	4.7*	5.5	5.1*	X	X	0.54	0.70*	X	X	0.03*	0.36*	X
United States												
Alamosa, Colorado	7.0	6.6	6.5	5.9	3.10*	2.60	1.80	0.80	0.20*	0.38	0.43	0.25
Atlantic City, New Jersey	4.7	4.1	4.5*	4.4	2.30	1.50	2.70*	1.20	0.59	0.89	0.66*	0.51
Bishop, California	X	X	6.2	6.2	X	X	0.50*	0.69	X	X	0.77*	0.27
Caribou, Maine	4.9	4.9	5.2	4.8	1.20	1.60	1.10	0.65	0.29	0.41	0.31	0.26
Glacier National Park, Montana	5.9	5.8	X	X	0.39	0.72	X	X	0.13	0.20	X	X
Huron, South Dakota	6.5*	6.7*	6.4	6.1	0.97*	0.67*	0.89	0.92	0.60*	1.30*	0.54	0.50
Macon County, North Carolina	4.7*	4.5	4.5	X	0.92*	0.90	0.77	X	0.23*	0.35	0.29	X
Mauna Loa, Hawaii	5.1*	4.6	5.0	5.7	0.56*	0.29	0.20	0.14	X	0.15	0.07	0.03
Meridian, Mississippi	4.7	4.7	4.7	4.7	0.74	0.69	0.75	0.74	0.23	0.28	0.27	0.27
Pendleton, Oregon	5.6	5.5	5.7	X	0.77	0.53	0.57	X	0.33	0.43	0.68	X
Raleigh, North Carolina	4.5	4.3	4.8*	X	0.94	1.00	0.87*	X	0.37	0.46	0.28*	X
Salem, Illinois	4.7	4.3	4.7*	4.4	1.60	1.10	2.60*	1.20	0.49	0.46	0.90*	0.47
San Angelo, Texas	X	6.1*	6.7	X	X	0.72*	1.60*	X	X	0.37*	0.53*	X
Tahlequah, Oklahoma	5.4	5.9	5.5	X	1.30	1.10	0.97	X	0.33	0.39	0.38	X
Victoria County, Texas	5.5	5.2	5.0	5.2	0.45	0.61	0.78	0.85	0.39	0.27	0.25	0.36
ASIA												
France												
New Amsterdam Island	X	X	X	5.0	X	X	X	0.11	X	X	X	X
India												
Allahabad	X	X	7.5	7.5	X	X	X	0.19	X	X	0.18*	0.70
Jodhpur	X	8.2*	7.3	7.5	1.30*	0.59	0.43*	0.21	0.58*	0.14	0.43	0.66
Kodaikanal	X	X	6.3*	6.7	X	0.26	0.06*	0.17	X	0.06	0.15	0.07
Minicoy	X	7.1	6.8	X	X	0.48*	0.17*	X	X	0.11*	0.14	X
Mohanbari	3.5*	X	6.5*	6.7	1.00	0.67	0.49*	0.26	0.59	0.94	1.10	0.77
Nagpur	X	X	6.4*	6.4	X	0.52*	0.19*	0.19	X	0.68*	0.40*	0.52
Port Blair	7.6*	X	6.3*	6.4	0.90	0.33	0.08*	0.32	0.16	0.18	0.11	0.54
Pune	7.4	7.4	6.9	6.9	1.10	0.78	0.07*	0.44	0.79	0.88	0.25	0.44
Srinagar	X	7.7	7.3	7.0	X	0.36	0.09*	0.38	X	0.50	0.30	0.72
Visakapatnam	X	7.6	6.8	6.6	X	1.40	0.96	0.49	X	0.91	0.67	1.50
Indonesia												
Jakarta	X	X	X	5.8	X	X	0.50*	X	X	X	X	0.57
Japan												
Ryori	5.6*	5.0	5.0	4.8	0.47*	0.63	0.48	0.56	0.12*	0.18	0.20	0.14
Malaysia												
Cameron Highlands	5.0*	5.2	5.2	5.4	1.60*	0.15*	0.13*	X	0.09*	0.35	0.09	0.36
EUROPE												
Austria												
Retz	X	X	4.7*	X	X	X	3.50*	X	X	X	1.10*	X
Czechoslovakia												
Chopok	X	4.3	4.3	4.3	X	2.40	2.40	2.10	X	0.64	0.57	0.53
Svratouch	4.3	4.3	4.4	4.5	2.40	2.30	2.10	2.00	0.78	0.65	0.65	0.61
Denmark												
Ejde (Faroes)	4.9	4.9	4.7	X	1.60	2.40	1.40	X	0.17	0.41	0.15	X
Finland												
Jokioinen	4.4	4.3	4.4	4.2	2.30	1.50	1.70	1.40	0.56	0.61	0.54	0.58
Sodankyla	4.7	4.6	4.7	4.6	0.65	0.58	0.56	0.59	0.23	0.27	0.20	0.21
France												
Abbeville	X	4.9	5.0	5.3	X	1.60	2.10	1.90	X	2.00	1.60	0.81
Carpentras	X	X	4.9	5.4	X	1.20	1.20	1.90	X	0.90	1.10	0.42
Chateauchinon	X	X	5.0	5.0	X	X	1.30	0.73	X	X	0.79	0.26
Gourdon	X	5.1	5.1	5.3	X	1.00	0.99	1.10	X	0.70	0.62	0.32
Phalsbourg	X	4.5	4.6	5.2	X	1.30	1.30	1.50	X	2.20	1.40	0.68
Rostrenen	X	5.2	5.3	5.4	X	1.20	0.70	1.00	X	0.77	0.59	0.38
German Dem Rep												
Neuglobsow	4.0	4.0	4.2	4.4	4.10	3.80	1.80	2.40	0.28	0.85*	0.59	0.65
Germany, Fed Rep												
Brotjacklriegel	4.4	4.3	4.2	4.6*	1.30*	1.50	1.30	2.20*	0.80*	0.82*	0.67	0.64*
Deuselbach	4.3*	4.3	4.2	4.2*	X	1.50	1.30	0.84*	0.63*	0.87	0.58	0.54*
Langenbrugge	4.2	4.0	4.0	4.1*	1.70*	2.80	2.40	1.70*	0.87	1.70	1.20	0.84*
Schauinsland	4.1	4.5	4.5	4.7*	X	0.81	0.85	0.58*	0.45	0.42	0.33	0.33*
Greenland												
Godhavn	5.8*	5.6	5.0	5.0*	1.00*	1.10	1.40	1.10*	0.10	0.15	0.07	0.06*
Pr. Christians Sund	5.8*	5.8*	X	X	0.97*	1.50*	X	X	0.05*	0.03*	X	X
Hungary												
Kecskemet	4.6	5.0	5.4	6.1	2.10	2.50	2.50	2.70	0.91	0.73	0.89	0.71
Ireland												
Valentia	5.6	5.2	5.5	5.8	1.30	1.30	0.87	0.62	0.17	0.13	0.12	0.12

Table 11.7

	Average Annual pH				Average Annual Concentration of Sulfate (milligrams per liter)				Average Annual Concentration of Nitrate (milligrams per liter)			
	1975–76	**1977–78**	**1979–80**	**1981–82**	**1975–76**	**1977–78**	**1979–80**	**1981–82**	**1975–76**	**1977–78**	**1979–80**	**1981–82**
Italy												
Monte Cimone	5.8	5.2	5.4	4.8	1.20	0.55	0.62	0.69	0.38	0.17	0.46	0.49
S. Maria de Leuca	5.6	5.9	5.5	5.1	1.40	0.76	0.73	0.48	0.10	0.24	0.51	0.40
Trapani	6.0*	6.1	6.6	X	0.91	0.84	0.76	X	0.76	0.14	0.10	X
Verona	X	X	4.7	X	X	X	0.87	X	X	X	0.77	X
Viterbo	5.2	5.3	5.2	5.0	1.20	0.74	0.58	0.61	0.07	0.12	0.64	1.20
Netherlands												
Witteveen	4.6	4.7	4.2*	4.5*	2.50	2.40	2.10*	1.50	0.72	0.91	0.95*	0.74*
Norway												
As	4.6	4.7	4.5	5.2*	2.50	2.00	2.60	1.60*	0.38	0.69	1.0	0.63*
Birkenes	4.3	4.2	4.1	4.3*	1.40	1.30	1.50	1.30*	0.58	0.62	0.63	0.48*
Kise	4.6	4.7	4.8	4.5*	1.50	2.20	1.60	1.30*	0.40	0.62	0.50	0.62*
Poland												
Suwalki	4.7*	4.7	4.7	4.5	2.70*	2.20	2.10	2.10	0.80	0.66	0.70	0.66
Portugal												
Barreiro	X	X	6.2*	6.2	X	X	1.60*	1.50	X	X	0.22*	0.26
Faro	X	X	6.7*	X	X	X	2.70*	X	X	X	X	X
Romania												
Fundata	X	X	5.7*	X	X	X	X	X	X	X	X	X
Paring	X	X	5.4*	X	X	X	2.30*	X	X	X	X	X
Rarau	X	X	5.7*	5.4	X	X	1.50*	2.50	X	X	0.22*	0.35
Semenic	X	X	5.0*	5.7	X	X	1.30*	3.20	X	X	0.13*	0.20
Stina de Vale	X	X	5.5*	X	X	X	1.50*	X	X	X	0.23*	X
Turia	X	X	5.5*	5.0	X	X	2.00*	2.10	X	X	0.28*	0.28
Sweden												
Bredkalen	5.4	5.0	4.9	4.9	1.00	0.89	0.81	0.62	0.28	0.24	0.19	0.23
Velen	4.4	4.4	4.4	4.3	1.40	1.30	1.30	1.10	0.51	0.49	0.69	0.43
Switzerland												
Jungfraujoch	X	6.1*	5.9	6.7	X	0.25*	0.45	0.33	X	0.13*	0.16	0.17
Payerne	X	5.8*	5.0	5.3	X	0.72*	1.20	1.60	X	0.38*	0.65	0.71
United Kingdom												
Eskdalemuir	X	5.2*	4.8*	X	X	1.20*	1.10*	X	X	0.23*	0.30*	X
Yugoslavia												
Lazaropole	5.1*	5.3	6.2	X	2.50*	2.70	1.70	2.20*	0.41*	0.22	0.16	X
Puntijarka	5.7	5.2	5.1*	X	2.20	1.80	3.30*	X	1.10	0.34	0.06*	X
USSR												
Irkutsk	X	6.6*	6.5*	X	X	1.50*	0.99*	0.77*	X	0.16*	0.22*	X
Kurgan	5.4*	6.3	5.9*	X	1.50*	2.90	3.60*	3.20*	0.25*	0.18*	0.20*	X
Novopjatigorsk	X	6.4*	6.6*	X	X	0.61*	1.40*	0.67*	X	0.15*	0.24*	X
Syktivkar	5.8	5.9	5.5*	X	1.50	1.40	1.20*	0.81	0.19	0.19*	0.12*	X
Turukhansk	5.5*	5.7	5.9	X	0.63*	0.77	0.75*	1.50*	0.58*	0.08	0.21*	X
OCEANIA												
Australia												
Cape Grim	X	X	X	X	X	X	X	X	X	X	X	X
United States												
Cape Matatula, Samoa	X	5.3	5.3	5.5	X	0.26	0.[illegible]7	0.18	X	0.05	0.04	0.02

Source: World Meteorological Organization; U.N. Environment Program.
* = one year's data missing; X = data not available.
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 11.1 Global Carbon Dioxide Emissions from Anthropogenic Sources, 1950–84

Source: Unpublished data from a database created for the U.S. Department of Energy by R.M. Rotty, Institute for Energy Analysis, Oak Ridge Associated Universities. These figures update Table 14 in: G. Marland and R. M. Rotty, "Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950–1982," *Tellus*, Vol. 36B, pp. 232–261 (1984); and U.S. Department of Energy, "Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950–1981," Report No. NBB-0036, unpublished.

Carbon emissions can be caused by natural or human factors. Volcanoes emit carbon dioxide, and long-term changes in global vegetation can contribute to, or withdraw from, the atmospheric carbon reservoir. Combustion of fossil fuels adds carbon to the atmosphere, as do gas flaring and cement production. Finally, clearing of forest land for agriculture emits carbon during the burning or decomposition of the biomass. This table presents estimates of anthropogenic emissions of carbon dioxide, but does not include carbon emissions from land clearing or natural processes.

Fossil fuel combustion releases carbon dioxide at rates that vary depending on the amount of each fuel type used (solid, liquid, and gas), the amount that is burned (a fraction is used for non-energy purposes), and the carbon content of the fuel that is burned. The energy database of the U.N. Statistical Office (UNSO) is the source for fuel production and disposition data. These data are reported in energy units: thousand terajoules for gases; metric tons of coal equivalent for solids; and tons of oil equivalent for liquids. National energy production data in physical units (barrels of oil, metric tons of coal, etc.) are converted to equivalent energy units by the UNSO using country- and year-specific conversion factors. (Refer to the Technical Note for Table 8.1 in Chapter 8, "Energy and Minerals," for details.) Since the energy content of a fuel is directly proportional to its carbon content, one can use fuel production data reported in energy units to estimate the amount of carbon dioxide released in combustion.

These data are not always directly usable for carbon budget studies. For example, traditional carbon analyses of coal have correlated carbon content with the gross heating value. (Gross heating value is the amount of heat that could be extracted from fuel combustion if the water vapor in the flue gases were condensed, releasing their latent heat of vaporization.) Recently, however, the UNSO has reported global coal production on a net heating value basis. An adjustment was therefore required to estimate the carbon content of global coal production.

Other adjustments were made in the analysis. For example, it was assumed that approximately 1 percent of the coal used by industry and power plants was unburned (coal dust and char), and a further few percent was converted to non-oxidizing uses (tar, benzene, etc.). Other oxidative reactions of coal (waste bank fires, coal bank fires, methane releases from coal mines, and carbon dioxide emissions from sulfur dioxide scrubbers) are assumed to be of negligible importance in carbon budget modeling.

Refer to the source document for a complete discussion of the data, underlying assumptions, and calculations used to prepare these estimates.

Table 11.2 Carbon Dioxide Emissions, by Country and Region, 1950, 1965, and 1983

Source: Unpublished data from a database created for the U.S. Department of Energy by R.M. Rotty, Institute for Energy Analysis, Oak Ridge Associated Universities.

These estimates of carbon emissions differ from those presented in Table 11.1. The basis for the calculations in Table 11.1 is *global fuel production*, while Table 11.2 is based on *national fuel consumption*. The author believes that the production method is more accurate on a global scale than the consumption method, but it cannot be used to provide estimates of national carbon emissions. The consumption method is more complex. Allowances must be made for international trade, air and sea bunkers, and stock changes. On a global scale, the difference between the two methods is quite small. For example, production data for 1950 yield an estimated carbon emission that is 3 percent higher than the estimate calculated from consumption data. The difference is approximately 4 percent in 1965, and 2 percent in 1983. The author estimates that the margin of error in the calculation of carbon emissions using fuel production data is 6-10 percent.

For further information, refer to the Technical Note for Table 11.1.

Table 11.3 Production and Release of Chlorofluorocarbons, 1931-84

Source: Chemical Manufacturers Association, "Production, Sales, and Calculated Release of CFC-11 and CFC-12 through 1984," Washington, D.C., October 1985.

The Chemical Manufacturers Association contracts with Alexander Grant and Company, Certified Public Accountants, to collect chlorofluorocarbon (CFC) production and sales data from companies based in countries of the Organization for Economic Co-operation and Development (OECD), and in India, Brazil, Venezuela, and Mexico. The data are examined for errors in reporting (double-counting of production by subsidiary and parent companies), inventory changes, and company-to-company sales of CFCs that might be double-counted. Alexander Grant and Company has collected annual production data for CFC-11 and CFC-12 from 1931 to the present.

Producing companies also provide information on the uses of their products: hermetically- and non-hermetically sealed refrigeration uses, open- and closed-cell foam blowing; aerosols; and solvents. Emissions of CFCs are estimated based on use-specific release factors. For example, all CFCs used in solvents, aerosols, and open-cell foam blowing are assumed to be released within six months of production. Refrigeration equipment and closed-cell foam blowing are assumed to have an early release peak due to product defects, with the remainder of the CFCs being released at a rate specific to the type of use. For example, hermetically-sealed refrigeration units are assumed to have an initial processing and filling loss of two percent, and a mean unit lifetime of 12 years. For details on the modelling of CFC releases, refer to R.L. McCarthy, *et al.*, "The Fluorocarbon-Ozone Theory-I," *Atmospheric Environment* Vol. 11, pp. 491-97 (1977).

Data are not available for CFC producers in India (one company reported data in 1983 and 1984), Eastern Europe, the People's Republic of China (PRC), and the Soviet Union. The Soviet Union is thought to be the largest producer of the group. In 1975, it was estimated that the Soviet Union produced about 7,500 metric tons of CFC-11 and 32,000 metric tons of CFC-12. These levels of production were equal to about 2 percent and 10 percent of reported world production of CFC-11 and CFC-12, respectively. More recent authoritative data are not available. Data for India (except one company in 1983 and 1984), Eastern Europe, the PRC, and the Soviet Union are excluded from this table.

Table 11.4 Carbon Dioxide in the Atmosphere, 1958-85

Sources: Data for Mauna Loa and South Pole: C.D. Keeling, Scripps Institution of Oceanography, unpublished data. Data for Barrow and Samoa: U.S. National Oceanic and Atmospheric Administration (NOAA), *Geophysical Monitoring for Climatic Change: Summary Report 1983* (NOAA, Boulder, Colorado, December 1984), and unpublished data.

Data for Mauna Loa, Barrow, and Samoa are collected and analyzed by *in situ* nondispersive infrared (NDIR) gas analyzers. These instruments monitor the carbon dioxide fraction of air on a continous basis; the data are then aggregated into hourly, daily, and monthly averages. The annual mean is the mean of the monthly averages. Samples are collected at the South Pole in three five-liter flasks twice a month, and are transported to the Scripps Institution of Oceanography for analysis using an NDIR analyzer. The annual mean figures for the South Pole and Mauna Loa were derived from interpolated data; 12 months of data were not available for all years. For details on this procedure, see R.B. Bacastow, *et al.*, "Seasonal Amplitude Increase in Atmospheric CO_2 Concentration at Mauna Loa, Hawaii, 1959-1982," *Journal of Geophysical Research*, Vol. 90, p. 529ff (1985).

Annual means disguise large seasonal variations in carbon dioxide concentrations. In April 1974 at Barrow, Alaska the concentration of carbon dioxide was 337.1 parts per million, volume (ppmv); the August mean concentration was 323.5 ppmv, a difference of 13.6 ppmv. This seasonal variation in carbon dioxide concentration is caused by carbon uptake by photosynthetic plants during the summer months.

The data for all monitoring sites undergo revision for several years after they are collected. Data are corrected for several reasons: drift in instrument calibration (analyzers are recalibrated every few years against standards, necessitating revision of data collected between calibrations); hardware changes (moving the analyzer's sampling intake has a significant impact on the data); and perturbations to "background" conditions (e.g. random carbon dioxide emissions from the Mauna Loa volcano must be edited out of the data set). The sum of these revisions is not very large, but it is important to note that data collected since 1983 are provisional, having been collected since the 1982 instrument calibration. Data collected prior to 1983 are largely in final form, although there may be some further editing until "final" values are reached. The latest data may be obtained from the Carbon Dioxide Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Details concerning data collection, revisions, and analysis are contained in the National Oceanic and Atmospheric Administration (NOAA) source and in: C.D. Keeling, *et al.*, "Measurement of the Concentration of Carbon Dioxide at Mauna Loa Observatory, Hawaii," in *Carbon Dioxide Review: 1982*, W.C. Clark, Ed. (Oxford University Press, New York, 1982); C.D. Keeling, *et al.*, "Atmospheric Carbon Dioxide Variations at the South Pole," *Tellus*, Vol. 28, No. 6 (1976); and in a forthcoming article by C.D. Keeling in *Tellus*.

Table 11.5 Concentrations of Sulfur Dioxide in Urban Areas, 1973-80

Sources: World Health Organization (WHO) and U.N. Environment Program (UNEP) *Urban Air Pollution, 1973-80* (WHO, Geneva, 1984); and unpublished data from the Monitoring and Assessment Research Center, University of London, United Kingdom.

Sites are monitoring stations. They are classified by location as center city or suburban, and further classified as industrial, commercial, or residential depending on the predominant use of land surrounding the monitoring station.

A site-year is the number of representative annual average values for all sites in a city. The maximum number is eight for each site for the period covered in the table.

Data for representative sites are submitted by national governments to the Global Environmental Monitoring System (GEMS) maintained by the World Health Organization and the U.N. Environment Program. By 1983, there were 50 countries with approximately 75 cities and 175 sites participating in the project. The coverage of stations and data is substantially better for the northern hemisphere where most large industrial cities are located.

Fewer data are available from developing countries, in part because the GEMS program did not become fully operational until after 1976.

The average is the mean of all representative daily values over the period 1973–80; the range is the high and low values over the same period. Trends have been determined for sites that have five or more years of data, by comparing first and second halves of the monitoring period. Trends are expressed as a percentage change per year.

Table 11.6 Concentrations of Suspended Particulate Matter in Urban Areas, 1973–80

Sources: World Health Organization (WHO) and U.N. Environment Program (UNEP) *Urban Air Pollution, 1973–80* (WHO, Geneva, 1984); and unpublished data from the Monitoring and Assessment Research Center, University of London, United Kingdom.

For a discussion of the urban air pollution project within the Global Environment Monitoring System (GEMS), refer to the Technical Note for Table 11.5.

Table 11.7 Precipitation Chemistry Monitoring, 1975–82

Sources: Data for 1975–80: The World Meteorological Organization (WMO), the U.S Environmental Protection Agency (EPA), the U.S. National Oceanic and Atmospheric Administration (NOAA), and the U.N. Environment Program's Global Environmental Monitoring System (UNEP-GEMS), *Global Atmospheric Background Monitoring for Selected Environmental Parameters: BAPMoN Data for 1975, 1976, 1977, 1978, 1979, and 1980* (National Climate Data Center, Asheville, North Carolina, United States, 1978, 1980, 1981, 1983, and 1984). Data for 1981–82: unpublished data from WMO and the Monitoring and Assessment Research Center (MARC), University of London, United Kingdom.

The WMO Background Air Pollution Monitoring Network (BAPMoN) includes stations worldwide that monitor turbidity, CO_2, particulates, and precipitation chemistry at sites far from human sources of air pollution. The goal of the program is to determine current levels of pollution and to identify long-term trends in the concentration of pollutants that may induce climate changes and other effects.

Established in 1970, the network consisted of 115 stations in 43 countries in 1984. Data from 84 stations in 32 countries are reported in the table. Most stations collect data from wet deposition only. Dry deposition can be the predominant source in arid areas, but it is not yet monitored with comparable accuracy.

Annual averages were calculated for sites where at least six monthly observations were recorded.

The data for sulfate concentrations at Sable Island (Canada) and American Samoa have been corrected for sea salt.

Concentrations for SO_4 (sulfate) and NO_3 (nitrate) are expressed in terms of the sulfur and nitrogen components.

pH is a logarithmic measure of acidity. A pH of 7 indicates neutrality; below 7 is acidic, above 7 is alkaline. A decline in pH from 6.0 to 5.0 is equivalent to a ten-fold increase in acidity.

12. Policies and Institutions

The growing concern for environmental conservation and resource management has stimulated the creation of new institutions, laws, and information.

Table 12.1 lists the countries that have ratified some of the most important environmental treaties and conventions of the past 20 years. The list is current as of December 1984. Included are global conventions that deal with the conservation of nature (species and ecosystems), marine pollution, and weapons and the environment.

Conventions that deal with worker safety and consumer products are excluded, as are the hundreds of bilateral and regional conventions that cover transboundary air pollution, weather modification, water use and storage, hunting and fishing rights and quotas, research and monitoring, and other environmental and resource issues for which international agreements are an important aspect of policy.

Regional Seas Conventions, negotiated under the auspices of the United Nations Environment Program (UNEP), have been signed for the Mediterranean Sea, the Persian Gulf, the West and Central African coast, the Southeast Pacific, the Red Sea and Gulf of Aden, and the Wider Caribbean. On March 22, 1985, the Vienna Convention for the Protection of the Ozone Layer was adopted at a conference sponsored by UNEP. It is now undergoing ratification. In addition to formal treaties, UNEP has assisted member countries with Policy Guidelines and a Code of Practice for the Management of Hazardous Wastes (1981); a Provisional Notification Scheme for Banned and Severely Restricted Chemicals (1984); and the Montreal Guidelines for the Protection of the Marine Environment Against Pollution from Land-Based Sources (1985).

Signing and ratifying treaties does not mean countries will abide by the conditions. Environmental conventions have few if any enforcement mechanisms, and countries with the most to lose (or gain) may simply refuse to participate.

Table 12.2 shows countries that have prepared or are preparing environmental and natural resource reports of various kinds. Basically, two kinds of reports have been included: assessments of environmental quality and natural resources, and compendia of statistics. The table is intended to be current as of fall 1985 but, because there is no single clearinghouse for this kind of information, reports from some countries may have been overlooked.

The most ambitious of these reports are the National Conservation Strategies in which various groups within a country, along with the government, attempt to spell out how the resources of the country will be used to support long-term, sustainable development. In 1984, the Conservation for Development Center of the International Union for Conservation of Nature and Natural Resources (IUCN), supported by the U.S. Agency for International Development (U.S. AID), published *A Framework for Sustainable Development* to give advice to and support for countries undertaking the task of preparing National Conservation Strategies.

In the early 1970s, Japan and the United States were the first countries to prepare official state-of-the-environment reports on a periodic basis. By the 1980s, a number of other developed and developing countries (Malaysia, India, the Philippines, and Chile, for example) had published or were in the process of preparing such reports. In August 1985, UNEP published *Guidelines for the Preparation of National State of the Environment Reports*, a checklist of items countries should consider in preparing material for reports.

In 1976, U.S. AID initiated the development of a series of environmental profiles for developing countries. In the first round, 39 draft profiles were prepared and circulated informally to governments and others. U.S. AID is now sponsoring the preparation of Phase II Environmental Profiles, encouraging national governments and indigenous organizations to do the work.

General statistical reports are prepared by almost all governments. In most cases, these reports contain useful data on temperature and precipitation, water resources, agricultural production, population, natural catastrophes, transportation, energy production and consumption, national parks, etc. A few countries have begun to publish separate reports on environmental indicators, statistics, and trends. UNEP, in conjunction with the Monitoring and Assessment Research Center (London), the World Resources Institute (Washington), and the International Institute for Environment and Development (London/Washington), is preparing an environmental data report that will make natural resource and environmental quality data more readily available to users in developing countries.

Table 12.1 PARTICIPATION IN GLOBAL CONVENTIONS PROTECTING

	Wetlands (Ramsar) 1971	World Heritage (Paris) 1972	Endangered Species (Washington) 1973	Migratory Species (Bonn) 1979	Ocean Dumping (London, Mexico, Moscow, Washington) 1972	Pollution from Ships (London) 1973	Law of the Sea (Montego Bay) 1982	Nuclear Test Ban (Moscow) 1963	Biological and Toxin Weapons (London, Moscow, Washington) 1972	Regional Seas (UNEP)
WORLD										
AFRICA										
Algeria	X	X	X							M,ML
Angola										
Benin		X	X					X	X	
Botswana			X					X		
Burkina Faso										
Burundi		X								
Cameroon		X	X	X						WCA
Cape Verde					X			X	X	
Central African Rep		X	X					X		
Chad								X		
Comoros										
Congo			X						X	
Djibouti										
Egypt		X	X	X				X		M,ML,MSP
Equatorial Guinea										
Ethiopia		X							X	
Gabon					X			X		
Gambia			X				X	X		
Ghana		X	X				X	X	X	
Guinea		X	X							WCA
Guinea-Bissau								X	X	
Ivory Coast		X					X	X		WCA
Kenya			X		X	X		X	X	
Lesotho									X	
Liberia			X					X		
Libya		X			X			X		M
Madagascar		X	X					X		
Malawi		X	X					X		
Mali		X								
Mauritania	X	X						X		
Mauritius			X					X	X	
Morocco	X	X	X		X			X		M
Mozambique		X	X							
Niger		X	X	X				X	X	
Nigeria		X	X		X			X	X	WCA
Rwanda			X					X	X	
Senegal	X	X	X					X	X	WCA
Sierra Leone								X	X	
Somalia										
South Africa	X		X		X			X	X	
Sudan		X	X					X		R
Swaziland								X		
Tanzania, United Rep		X	X					X		
Togo			X					X	X	WCA
Tunisia	X	X	X		X	X		X	X	M,ML,MSP
Uganda								X		
Zaire		X	X		X			X	X	
Zambia		X	X					X		
Zimbabwe		X	X				X			
NORTH AMERICA										
Barbados									X	
Canada	X	X	X		X			X	X	
Costa Rica		X	X					X	X	
Cuba		X			X		X		X	
Dominican Rep					X			X	X	
El Salvador								X		
Guatemala		X	X		X			X	X	
Haiti		X			X					
Honduras		X	X		X			X	X	
Jamaica		X					X		X	
Mexico		X			X		X	X	X	C
Nicaragua		X	X					X	X	
Panama		X	X		X			X	X	
Trinidad and Tobago			X					X		
United States		X	X		X			X		C
SOUTH AMERICA										
Argentina		X	X		X				X	
Bolivia		X	X					X	X	
Brazil		X	X		X			X	X	
Chile	X	X	X	X	X			X	X	
Colombia		X	X			X				
Ecuador		X	X					X		SEP
Guyana		X	X							
Paraguay			X						X	
Peru		X	X			X		X		
Suriname			X		X			X		
Uruguay	X		X			X		X	X	
Venezuela			X					X	X	

THE ENVIRONMENT, 1984

Table 12.1

	Wetlands (Ramsar) 1971	World Heritage (Paris) 1972	Endangered Species (Washington) 1973	Migratory Species (Bonn) 1979	Ocean Dumping (London, Mexico, Moscow, Washington) 1972	Pollution from Ships (London) 1973	Law of the Sea (Montego Bay) 1982	Nuclear Test Ban (Moscow) 1963	Biological and Toxin Weapons (London, Moscow, Washington) 1972	Regional Seas (UNEP)
ASIA										
Afghanistan		X			X			X	X	
Bahrain										P
Bangladesh		X	X							
Bhutan								X	X	
Burma								X		
China			X					X	X	
Cyprus										M
India	X	X	X	X				X	X	
Indonesia			X					X		
Iran	X	X	X					X	X	P
Iraq		X						X		P
Israel			X	X				X		M
Japan	X		X		X			X	X	
Jordan	X	X	X		X	X		X	X	
Kampuchea, Dem									X	
Korea, Dem Peoples Rep										
Korea, Rep								X		
Kuwait								X	X	P
Lao Peoples Dem Rep								X	X	
Lebanon		X						X	X	M
Malaysia			X					X		
Mongolia								X	X	
Nepal		X	X					X		
Oman		X			X					P
Pakistan	X	X	X						X	
Philippines			X		X		X	X	X	
Qatar		X							X	P
Saudi Arabia		X							X	P
Singapore								X	X	
Sri Lanka		X	X					X		
Syrian Arab Rep		X						X		M
Thailand			X					X	X	
Turkey		X						X	X	M ML
United Arab Emirates			X		X					P
Viet Nam									X	
Yemen		X				X				R
Yemen, Dem		X						X	X	
EUROPE										
Albania										
Austria	X		X					X	X	
Belgium			X			X		X	X	
Bulgaria	X	X						X	X	
Czechoslovakia								X	X	
Denmark	X	X	X	X	X			X	X	
Finland	X		X		X			X	X	
France		X	X		X					M ML
German Dem Rep	X		X		X			X	X	
Germany, Fed Rep	X	X	X	X	X	X		X	X	
Greece	X	X			X			X	X	M
Hungary	X			X	X	X		X	X	
Ireland				X	X			X	X	
Italy	X	X	X	X	X	X		X	X	M ML MSP
Luxembourg		X		X				X	X	
Malta		X						X	X	M
Netherlands	X		X	X	X			X	X	C
Norway	X	X	X		X	X		X	X	
Poland	X	X			X			X	X	
Portugal	X	X	X	X	X				X	
Romania								X	X	
Spain	X	X		X	X			X	X	M ML
Sweden	X		X	X	X			X	X	
Switzerland	X	X	X		X			X	X	
United Kingdom	X	X	X		X	X		X	X	
Yugoslavia	X	X			X	X		X	X	M
USSR	X		X		X			X	X	
OCEANIA										
Australia	X	X	X					X	X	
Fiji							X	X	X	
New Zealand	X				X			X	X	
Papua New Guinea			X		X			X	X	
Solomon Islands					X				X	
ANTARCTICA										

Source: U. N. Environment Program.
X = ratified member; other symbols refer to specific Regional Sea conventions, described in the Sources and Technical Notes.
For additional information, see Sources and Technical Notes.

Table 12.2 NATIONAL AND REGIONAL SOURCES OF

	National Conservation Strategy	U.S. AID Phase I Draft Environmental Profile	U.S. AID Phase II Environmental Profile	State of the Environment Report	U.S. Foreign Disaster Assistance Country Profile	Country Statistical Yearbook	Environmental Statistical Report	Regional Report on Resources and the Environment	INFOTERRA Participant
WORLD									
AFRICA									
Algeria						P			I
Angola						P			
Benin									I
Botswana	U					P			I
Burkina Faso		P80	P	U(G)	P82	P			I
Burundi		P81				P		P84(NGO)	I
Cameroon		P81				P			I
Cape Verde		P80			P84	P			I
Central African Rep						P			I
Chad					P82	P			
Comoros					P84				I
Congo						P			I
Djibouti					P81	P			
Egypt		P80				P			I
Equatorial Guinea						P			
Ethiopia					P81	P			I
Gabon						P			I
Gambia		P			P82	P			I
Ghana		P80			P85	P			I
Guinea	D	P83							I
Guinea-Bissau	D					P			I
Ivory Coast	D					P			I
Kenya					P81	P		P84(NGO)	I
Lesotho		P82				P			
Liberia		P80				P			I
Libya						P			I
Madagascar	P84				P84	P			I
Malawi		P82				P			I
Mali		P80			P83*	P			I
Mauritania		P79	P		P84	P			I
Mauritius					P84	P			I
Morocco		P81				P			I
Mozambique					P*	P			
Niger		P80			P85	P			I
Nigeria						P			I
Rwanda		P81				P		P84(NGO)	I
Senegal	U	P80			P82	P			I
Sierra Leone	D					P			
Somalia					P81	P			I
South Africa	P80					P			
Sudan		P		U(G)	P81	P			I
Swaziland		P80				P			
Tanzania, United Rep					P81	P		P84(NGO)	I
Togo						P			I
Tunisia		P80				P			I
Uganda	U	P82			P81	P		P84(NGO)	I
Zaire	D	P	P		P82	P			I
Zambia	P85	P82			P81	P			I
Zimbabwe	U	P82				P			
NORTH AMERICA									
Barbados		P			P82	P		P82(NGO)	I
Canada	D			U(G)85		P	U85	P79,85(IGO)	I
Costa Rica	D	P	P		P82	P		P82(NGO)/U85(NGO)	I
Cuba						P		P82(NGO)	
Dominican Rep			P		P84	P		P82(NGO)	
El Salvador		P82	P		P84	P		P82(NGO)/U85(NGO)	I
Guatemala		P81	P		P82	P		P82(NGO)/U85(NGO)	I
Haiti		P79	P85		P84	P		P82(NGO)	
Honduras		P81	P		P81	P		P82(NGO)/U85(NGO)	I
Jamaica		P	U		P83	P		P82(NGO)	I
Mexico	D					P		P82(NGO)	I
Nicaragua		P81			P81	P		P82(NGO)/U85(NGO)	
Panama			P			P		P82(NGO)/U85(NGO)	I
Trinidad and Tobago					P82	P		P82(NGO)	
United States				a		P	P79	P79,85(IGO)	I
SOUTH AMERICA									
Argentina	D					P		P82(NGO)	I
Bolivia		P80	P		P84	P		P82(NGO)	I
Brazil	D					P		P82(NGO)	I
Chile				P(NGO)85	P80*	P		P82(NGO)	I
Colombia						P		P82(NGO)	I
Ecuador		P79	P		P83	P		P82(NGO)	I
Guyana		P			P82	P		P82(NGO)	I
Paraguay			P			P		P82(NGO)	I
Peru		P79	U		P83	P		P82(NGO)	I
Suriname									
Uruguay						P		P82(NGO)	I
Venezuela	D					P		P82(NGO)	I

ENVIRONMENTAL INFORMATION, 1970–85

Table 12.2

	National Conservation Strategy	U.S. AID Phase I Draft Environmental Profile	U.S. AID Phase II Environmental Profile	State of the Environment Report	U.S. Foreign Disaster Assistance Country Profile	Country Statistical Yearbook	Environmental Statistical Report	Regional Report on Resources and the Environment	INFOTERRA Participant
ASIA									
Afghanistan						P		P84(IGO)	
Bahrain						P			I
Bangladesh	D	P80			P83	P		P84(IGO)	I
Bhutan								P84(IGO)	
Burma		P82			P80	P		P84(IGO)	
China	D			U(IGO)83		P		P84(IGO)	I
Cyprus						P			I
India	D	P80		P(NGO)85	P83	P		P84(IGO)	I
Indonesia	D	P			P83	P		P84(IGO)	I
Iran						P		P84(IGO)	
Iraq						P			I
Israel						P			I
Japan				P(G)70-85		P	P80	P79,85(IGO)/P84(IGO)	I
Jordan	U	P79				P			I
Kampuchea, Dem						P		P84(IGO)	
Korea, Dem Peoples Rep								P84(IGO)	
Korea, Rep						P		P84(IGO)	I
Kuwait						P			I
Lao Peoples Dem Rep						P		P84(IGO)	
Lebanon						P			I
Malaysia	D			P(NGO)84		P		P84(IGO)	I
Mongolia						P		P84(IGO)	I
Nepal	U	P79			P83	P		P84(IGO)	I
Oman	D	P81				P			I
Pakistan	D	P81			P83	P	P84	P84(IGO)	I
Philippines	U	P80		P(G)83	P82	P	P79	P84(IGO)	I
Qatar						P			I
Saudi Arabia				U(G)84		P			I
Singapore						P		P84(IGO)	
Sri Lanka	U	P78	P		P83	P		P84(IGO)	I
Syrian Arab Rep		P81				P			I
Thailand	D	P79				P		P84(IGO)	I
Turkey			P	P(NGO)	P82	P		P79,85(IGO)	I
United Arab Emirates						P			I
Viet Nam	P85					P		P84(IGO)	I
Yemen		P82				P			I
Yemen, Dem						P			
EUROPE									
Albania						P			
Austria				P(G)		P	P82	P79,85(IGO)	I
Belgium				P(G)79		P		P79,85(IGO)	I
Bulgaria						P			I
Czechoslovakia	D					P			I
Denmark				P(G)		P		P79,85(IGO)	I
Finland				P(G)85		P	P80	P79,85(IGO)	I
France	D			P(G)78-85		P	P83	P79,85(IGO)	I
German Dem Rep						P			I
Germany, Fed Rep				P(NGO)		P	P79	P79,85(IGO)	I
Greece	D					P		P79,85(IGO)	I
Hungary						P	P81		I
Ireland				P(G)85		P		P79,85(IGO)	I
Italy	U			P(G)		P	P	P79,85(IGO)	I
Luxembourg				P(G)		P		P79,85(IGO)	
Malta						P			I
Netherlands	D			P(G)		P	P80	P79,85(IGO)	I
Norway	D					P	P83	P79,85(IGO)	I
Poland				P(G)85		P	P79		I
Portugal						P		P79,85(IGO)	I
Romania						P			I
Spain	D			P(G)		P		P79,85(IGO)	I
Sweden				P(G)83		P	P81	P79,85(IGO)	I
Switzerland						P		P79,85(IGO)	I
United Kingdom	P83					P	P80	P79,85(IGO)	I
Yugoslavia				P(G)80		P	P79	P79,85(IGO)	I
USSR						P			I
OCEANIA									
Australia	P83			P(G)85		P	P83	P79,85(IGO)/P84(IGO)	I
Fiji	D				P80	P		P84(IGO)	I
New Zealand	P85					P		P79,85(IGO)/P84(IGO)	I
Papua New Guinea					P85	P		P84(IGO)	
Solomon Islands						P		P84(IGO)	
ANTARCTICA									

Sources: World Resources Institute, International Institute for Environment and Development.
P = published; U = unpublished; D = under discussion; * = publication being updated; IGO = prepared by an international governmental organization; NGO = prepared by a non-governmental organization; G = prepared by a governmental organization; I = participant in the UNEP INFOTERRA program. a = P(G)70-83/P(NGO)82,84
For additional information, see Sources and Technical Notes.

Sources and Technical Notes

Table 12.1 Participation in Global Conventions Protecting the Environment, 1984

Source: United Nations Environment Program (UNEP), "Environmental Law in the United Nations Environment Programme" (UNEP, Nairobi, 1985).

As requested by the U.N. General Assembly, the UNEP Environmental Law Unit maintains a *Register of International Treaties and other Agreements in the Field of the Environment*, which summarizes the content and current membership status of more than 100 multilateral conventions and protocols. The Register is updated periodically and copies are sent to member states for review. One of the principal aims of this activity is to promote the wider acceptance and use of existing international legal instruments by governments. The complete titles of the conventions and treaties are:

1. Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar, 1971);
2. Convention Concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972);
3. Convention on International Trade in Endangered Species of Wild Fauna and Flora (Washington, 1973);
4. Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979);
5. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London, Mexico, Moscow, Washington, 1972);
6. International Convention for the Prevention of Pollution from Ships (London, 1973);
7. United Nations Convention on the Law of the Sea (Montego Bay, 1982);
8. Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and Under Water (Moscow, 1963);
9. Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons, and on their Destruction (London, Moscow, Washington, 1972).

Some of the symbols used to indicate ratification of a Regional Sea Convention actually indicate ratification of several related conventions and protocols.

The full titles of Regional Seas Conventions and the letters used in the table to abbreviate them are listed below.

M = Convention for the Protection of the Mediterranean Sea Against Pollution (1976). Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft (1976). Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency (1976).

ML = Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-based Sources (1980).

MSP = Protocol Concerning Mediterranean Specially Protected Areas (1982).

WCA = Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (1981). Protocol Concerning Co-operation in Combating Pollution in Cases of Emergency (1981).

R = Regional Convention for the Conservation of the Red Sea and Gulf of Aden (1982). Protocol Concerning Regional Co-operation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency (1982).

SEP = Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific (1981). Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Oil and Other Harmful Substances in Cases of Emergency (1981). Supplementary Protocol to the Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Oil and Other Harmful Substances in Cases of Emergency (1983). Protocol for the Protection of the South-East Pacific Against Pollution from Land-based Sources (1983).

C = Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (1983). Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region (1983).

Table 12.2 National and Regional Sources of Environmental Information, 1970-85

Sources: National Conservation Strategies: International Union for Conservation of Nature and Natural Resources (IUCN), *National Conservation Strategies: A Report to Development Assistance Agencies on Progress and Priorities in Planning for Sustainable Development*, (IUCN, Gland, Switzerland, June 1983), draft; *World Conservation Strategy in Action*, (IUCN Bulletin Supplement No. 4), September 1985, p. 8.

U.S. AID Phase I Draft Environmental Profiles: List from the Office of Arid Land Studies, University of Arizona, January 1985.

U.S. AID Phase II Environmental Profiles: List from the International Institute for Environment and Development, October 1985; U.S. Agency for International Development and U.S. National Park Service, *Natural Resource Technical Bulletin*, No. 5, Spring 1984.

State-of-the-Environment Reports: Various sources.

Foreign Disaster Assistance Reports: List from the Office of Foreign Disaster Assistance, U.S. AID, November, 1985.

Statistical Yearbooks: U.N. Statistical Office, *Directory of Environment Statistics*, (United Nations, New York, 1983), and other sources.

Environmental Statistical Reports: List from the U.N. Statistical Office, November 1985, and other sources.

Regional Reports on Natural Resources and the Environment: Organization for Economic Co-operation and Development, *State of the Environment 1985* (OECD, Paris, 1985); U.N. Economic and Social Commission for Asia and the Pacific, *State of the Environment in Asia and the Pacific* (United Nations, Bangkok, 1984); Program for International Development, *Renewable Resource Trends in East Africa*, (Clark University, Worcester, Massachusetts, 1984); M.J. Dourojeanni, *Renewable Natural Resources of Latin America and the Caribbean, Situation and Trends* (World Wildlife Fund, Washington, D.C., 1982); International Institute for Environment and Development, *Natural Resources and Economic Development in Central America* (International Institute for Environment and Development (IIED), Washington D.C., 1985) draft.

INFOTERRA Participants: List provided by UNEP, September 1985. INFOTERRA, the International Referral System for Sources of Environmental Information, is a network of national focal points—centers of information—established by UNEP for the exchange of environmental information. At present, INFOTERRA focal points are located in 126 countries, including 103 developing countries. The system handles about 750 inquiries per month; most of these concern pollution control technology, chemicals, atmosphere and climate, environmental monitoring, and management and planning.

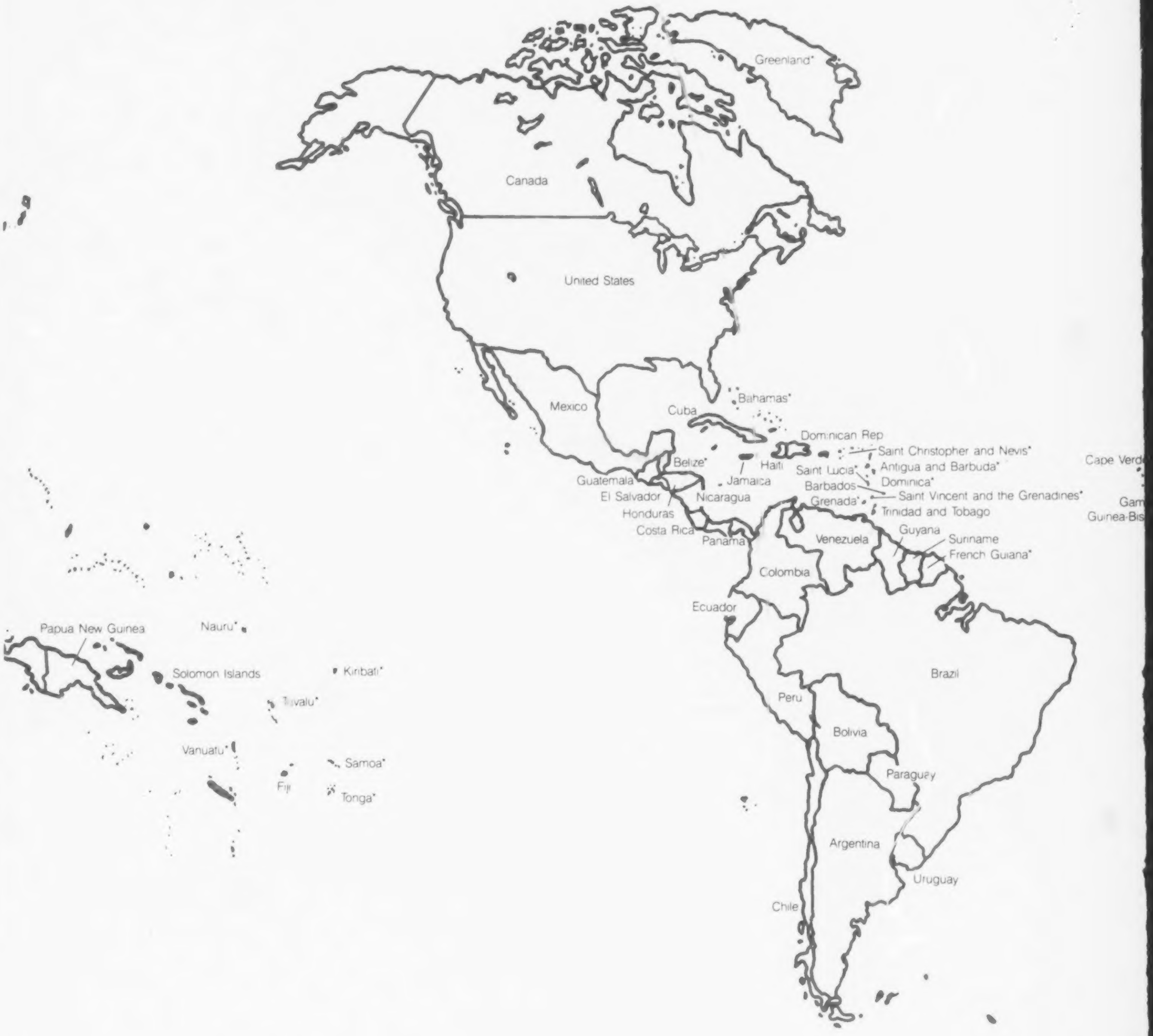
National Conservation Strategy reports refer to documents that have been prepared in support of the program. Some are endorsed by the national governments; others are not. Countries that are classified "D" (under discussion) are those that have adopted or endorsed a National Conservation Strategy plan of action or have some other involvement with the program. They may or may not produce a published document. For more detailed information on the status of National Conservation Strategies, see past issues of the *IUCN Bulletin Supplement*.

Appendixes

A: World Map

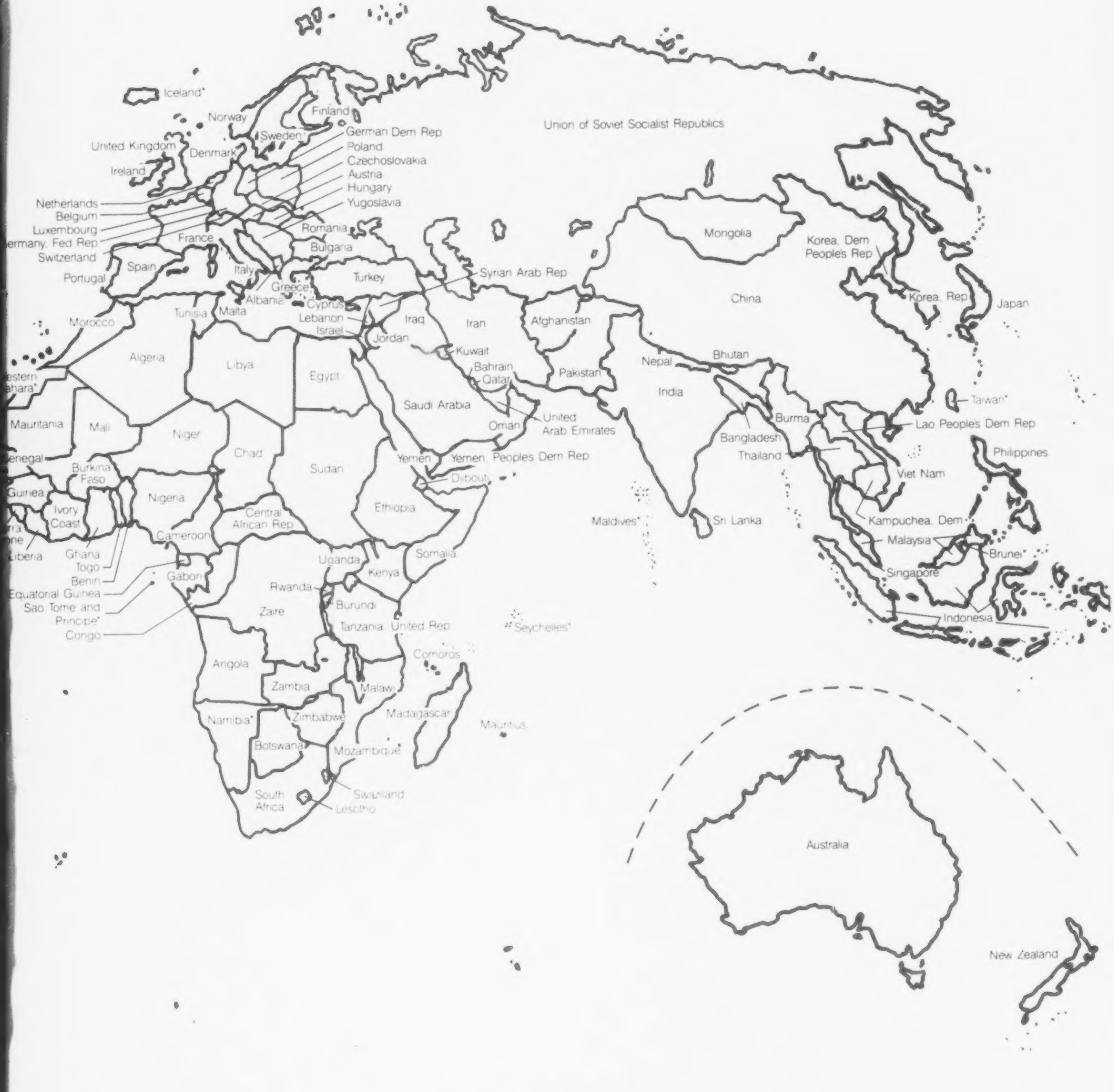
B: Organizations and Regional Groups

Appendix A: World Map



Greenland*
Canada
United States
Mexico
Bahamas*
Cuba
Dominican Rep
Saint Christopher and Nevis*
Belize*
Haiti
Saint Lucia*
Antigua and Barbuda*
Cape Verd
Guatemala
Jamaica
Dominica*
El Salvador
Nicaragua
Barbados
Saint Vincent and the Grenadines*
Gam
Honduras
Grenada*
Trinidad and Tobago
Guinea-Bis
Costa Rica
Panama
Venezuela
Guyana
Suriname
French Guiana*
Colombia
Ecuador
Papua New Guinea
Nauru*
Solomon Islands
Kiribati*
Tuvalu*
Brazil
Peru
Bolivia
Vanuatu*
Samoa*
Fiji
Tonga*
Paraguay
Argentina
Uruguay
Chile

*These countries are not included in the data tables in Part IV


Iceland*
Norway
Finland
Sweden
German Dem Rep
Poland
Czechoslovakia
Austria
Hungary
Yugoslavia
United Kingdom
Denmark
Ireland
Netherlands
Belgium
Luxembourg
ermany, Fed Rep
Switzerland
France
Romania
Bulgaria
Spain
Portugal
Italy
Greece
Albania
Turkey
Cyprus
Lebanon
Israel
Syrian Arab Rep
Union of Soviet Socialist Republics
Mongolia
Korea, Dem People's Rep
Korea, Rep
Japan
China
Morocco
Tunisia
Malta
Iraq
Iran
Afghanistan
Jordan
Kuwait
Bahrain
Qatar
Pakistan
Nepal
Bhutan
India
estern ahara*
Algeria
Libya
Egypt
Saudi Arabia
United Arab Emirates
Oman
Taiwan*
Burma
Lao People's Dem Rep
Bangladesh
Thailand
Mauritania
Mali
Niger
Chad
Sudan
Yemen
Yemen, Peoples Dem Rep
Djibouti
enegal
Burkina Faso
Guinea
Nigeria
Ethiopia
Philippines
Viet Nam
Ivory Coast
rra one
Central African Rep
Maldives*
Sri Lanka
Kampuchea, Dem
Cameroon
Liberia
Ghana
Togo
Benin
Equatorial Guinea
Sao Tome and Principe*
Congo
Gabon
Uganda
Somalia
Kenya
Malaysia
Brunei*
Singapore
Rwanda
Burundi
Zaire
Indonesia
Tanzania, United Rep
Seychelles*
Comoros
Angola
Zambia
Malawi
Madagascar
Mauritius
Namibia*
Zimbabwe
Botswana
Mozambique
Swaziland
South Africa
Lesotho
Australia
New Zealand

Appendix B: Organizations and Regional Groups

ACPE—Asian Centrally Planned Economies

Burma, Union of
China, People's Republic of
Kampuchea, Democratic
Korea, Democratic People's Republic of
Lao People's Democratic Republic
Mongolia
Viet Nam

ASEAN—Association of Southeast Asian Nations

Brunei
Indonesia
Malaysia
Philippines
Singapore
Thailand

CIDIE—Committee of International Development Institutions on the Environment

A non-United Nations organization that examines the environmental aspects of economic development activities.

African Development Bank
Arab Bank for Economic Development in Africa
Asian Development Bank
Caribbean Development Bank
Commission of the European Communities
European Investment Bank
Inter-American Development Bank
The Organization of American States
The United Nations Development Program
The United Nations Environment Program
The World Bank

CMEA—Council for Mutual Economic Assistance

Bulgaria
Cuba
Czechoslovakia
German Democratic Republic
Hungary
Mongolia
Poland
Romania
Union of Soviet Socialist Republics
Viet Nam

DAC—Development Assistance Committee

A specialized committee of the Organization for Economic Co-operation and Development (OECD).

Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany, Federal Republic of
Italy
Japan
Netherlands
New Zealand
Norway
Sweden
Switzerland
United Kingdom
United States
Commission of the European Communities

ECE—Economic Commission for Europe

A United Nations organization consisting of countries from both Eastern and Western Europe and North America.

Eastern Europe
Bulgaria
Czechoslovakia
German Democratic Republic
Hungary
Poland
Union of Soviet Socialist Republics
  Byelorussian Soviet Socialist Republic
  Ukranian Soviet Socialist Republic

Western Europe
Austria
Belgium
Cyprus
Denmark
Finland
France
Germany, Federal Republic of
Greece
Iceland
Ireland
Italy
Luxembourg
Malta
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom
Yugoslavia

North America
Canada
United States

EEC—European Economic Community

Belgium
Denmark
France
Germany, Federal Republic of
Greece
Ireland
Italy
Luxembourg
Netherlands
Portugal
Spain
United Kingdom

IEA— International Energy Agency

An autonomous body within the Organization for Economic Co-operation and Development (OECD).

Australia
Austria
Belgium
Canada
Denmark
Germany
Greece
Ireland
Italy
Japan
Luxembourg
Netherlands
New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

Appendix B

IUCN—International Union for Conservation of Nature and Natural Resources

There are few countries in which the IUCN does not have a member organization. As of August 1984, IUCN's membership included 56 countries, 123 government agencies, 316 national and international non-governmental organizations, and 6 non-voting affiliates.

Least Developed Countries

In 1982, the United Nations General Assembly agreed upon the following three criteria for "least developed countries": a per capita gross domestic product of $285 or less, a share of manufacturing in total gross domestic product of 10 percent or less, and a literacy rate (the proportion of literate persons over 15 years of age) of 20 percent or less. In addition to countries meeting all three of these criteria, borderline cases (in which one criterion was met and the others nearly met) were also included.

Afghanistan
Bangladesh
Benin
Bhutan
Botswana
Burkina Faso
Burundi
Cape Verde
Central African Republic
Chad
Comoros
Djibouti
Equatorial Guinea
Ethiopia
Gambia
Guinea
Guinea-Bissau
Haiti
Lao People's Democratic Republic
Lesotho
Malawi
Maldives
Mali
Nepal
Niger
Rwanda
Samoa
São Tomé and Principe
Sierra Leone
Somalia
Sudan
Tanzania, United Republic of
Togo
Uganda
Yemen Arab Republic
Yemen, People's Democratic Republic

OECD—Organization for Economic Co-operation and Development

North America
Canada
United States

Europe
Austria
Belgium
Denmark
Finland
France
Germany, Federal Republic of
Greece
Iceland
Ireland
Italy
Luxembourg
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom
Yugoslavia (special participant)

Asia
Australia
Japan
New Zealand
Turkey

OPEC—Organization of Petroleum Exporting Countries

Algeria
Ecuador*
Gabon
Indonesia
Iran
Iraq
Kuwait
Libya
Nigeria
Qatar
Saudi Arabia
United Arab Emirates
Venezuela

SADCC—Southern African Development Coordination Conference

Angola
Botswana
Lesotho
Malawi
Mozambique
Swaziland
Tanzania, United Republic of
Zambia
Zimbabwe

SPF—South Pacific Forum

Australia
Cook Islands
Fiji
Kiribati
Nauru
New Zealand
Nive
Papua New Guinea
Solomon Islands
Tonga
Tuvalu
Vanuatu
Western Samoa

Sub-Saharan Countries

Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Chad
Comoros
Congo
Djibouti
Equatorial Guinea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Ivory Coast
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mozambique
Niger
Nigeria
Rwanda
São Tomé and Principe
Senegal
Seychelles
Sierra Leone
Somalia
Sudan
Swaziland
Tanzania, United Republic of
Togo
Uganda
Zaire
Zambia
Zimbabwe

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